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VARIETIES AND FORMS OF GROUNDNUT

(*Arachis hypogaea* Linn.)

THEIR CLASSIFICATION AND ECONOMIC CHARACTERS

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(With Plates IV to X)

THE groundnut or peanut is the wonder plant of the century. It is primarily an oilseed, but gives food for man and cattle, and renovates the soil on which it is grown. Though not a native of this country, the plant has literally yielded hundreds of millions of rupees to the Indian ryot. India till recently held a high position in the production and trade of groundnut in the world market.

Origin of groundnut and allied species

The botanical name of the plant is *Arachis hypogaea* Linn. *Arachis* is derived from a Greek word for a leguminous plant and the specific name *hypogaea* means below the ground, and refers to the formation of the pods in the soil. The native country or origin of this plant is still a matter of speculation, because it has never been found in the wild state in any country. But its cousins or allied species are found in the wild state only in South America. Therefore, it may be presumed that groundnut as it is now known in cultivation, must have originated in South America from some allied species. It may further be stated in this connection that groundnut was first met with in cultivation in South America from where it has spread to other countries.

De Candolle [1884] has discussed the subject at some length and indicated Brazilian origin of the species. Bentham [1859] considers that the cultivated groundnut is perhaps a form derived from one of the six species growing wild in Brazil. Originally seven species of *Arachis* were enumerated and subsequently another six species were described from South America. Chevalier [1933], however, seems to recognise only the following six species, viz. *A. glabrata* Benth ; *A. villosa* Benth ; *A. marginata* Gardner ; *A. paraguariensis* Shod and Hassler ; *A. pusilla* Benth ; and *A. hypogaea* Linn. Waldron [1919] has postulated that the cultivated bunch varieties are derived from a wild Brazilian species as *A. pusilla* which has an erect habit and the prostrate ones from *A. prostrata* (*A. africana* Lour.) another Brazilian species which has a spreading habit. Husted [1933 and 1936] has discussed the origin of *A. hypogaea* and does not support Waldron's suggestion of its dual origin, and the authors of this paper agree with Husted. Based upon the

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genetical studies made by several authors and in the light of cytological investigations carried out by himself, Mendes [1947] concludes that the cultivated peanut must be considered to be of a tetraploid nature. It seems likely that *Arachis hypogaea* probably arose spontaneously by chromosome doubling from diploid forms. It also seems probable that this took place in the State of Matto Grosso, Brazil, which is generally recognised as the place where peanut plants are indigenous. In this connection, it may be of interest to note that all the known diploid species (2n=20) occur in a wild state in the State of Matto Grosso, Brazil, and that the early Indians cultivated the tetraploid forms (2n=40) in the same region.

Sampson [1936] says that a wild plant considered to be an ancestral form of the groundnut has been collected by M. Gregorio Bondar in the State of Bahia, Brazil, and it has been described by Chevalier under the name *A. sylvestris*. Chevalier [1933] has, however, classed it as a sub-species of *A. hypogaea*, and he considers *A. sylvestris* as the likely connecting link between *A. pusilla* and the commercially grown varieties. Thus Brazil seems to be the most likely home of the groundnut plant.

The sub-species and varieties of groundnut

The various forms of the cultivated groundnut, *A. hypogaea* can be broadly classified into two groups based on their habit, viz. the bunch and the spreading. Waldron [1919] suggested that *A. hypogaea* may be divided into two sub-species, viz. *fastigiata* for the bunch and *procumbens* for the spreading. Patel and others [1936], who discussed the genetic constitution of the two sub-species, have, however, doubted the necessity for postulating separate origin for the two sub-species. There are, however, two so-called new groundnut 'species' viz. *A. nambyquarae* Hoehne and *A. rasteiro* Chev. These have large-sized pods with prominent reticulations and ruptured or partially developed seed coats. These characters distinguish them from all other known varieties of the groundnut. Chevalier [1933] who constructed the sub-species *A. oleifera* Chev. under *A. hypogaea* to include all the cultivated groundnut varieties, ranks the two new groundnuts as two sub-species of *A. hypogaea*. Husted [1933] who examined their somatic chromosomes along with those of *A. hypogaea* states that in the three 'species', the chromosomes are 'the same in number and also appear to be the same in size and that the *rasteiro* and the *nambyquarae* are utmost sub-species of *A. hypogaea*'. Luzina [1935], however, calls them only types and includes them in a basic group which, in his opinion, has probably served as initial forms from which all the cultivated and spreading forms have been derived. Hoehne [1941-1944] recognises 12 species, some of them having as many as five forms and others being divided into sub-species. He divides *A. hypogaea* into three forms, namely, *A. hypogaea*, L. forma *typica* Hœhne, *A. hypogaea* L. forma *macrocarpa* A. Chev., *A. hypogaea* L. forma *microcarpa* A Chev. He also includes all cultivated forms having 2n-40 chromosomes in two species groups, viz. *A. hypogaea* and *A. nambyquarae*. The authors

have, during the last 20 years, made number of crosses between the three 'species', viz. *A. rasteiro*, *A. nambyquarae* and *A. hypogaea* and found them to cross freely with one another. Further, there was no marked degree of sterility in any of the crosses, which is usually associated with inter-specific hybrids. Also the characters of pod and seed which distinguish the two new 'species' are found in other forms of *A. hypogaea*, though much less pronounced. Therefore, they are inclined to rank the new 'species' as only distinct botanical varieties of *A. hypogaea*.

The authors have studied the characters of the varieties and various forms of the groundnut available, both in the field and in the laboratory, and attempts are made in this paper to classify them into groups and sub-groups according to their affinities. Only five botanical varieties, viz. var. *oleifera* (*Arachis hypogaea* sub-species *oleifera chevalier*), var. *rasteiro*, var. *nambyquarae*, var. *asiatica* and var. *gigantae* are recognised here. All the cultivated groundnuts are described as forms of var. *oleifera*. The measurements of each form which are true for Tindivanam conditions are given in a tabular statement (Appendix II). Though they may vary with soil and climatic conditions elsewhere, the relative idea given by the figures will be of use to the breeder, if not wholly, to the systematist. The artificial key appended (Appendix IV) will be found useful in identifying the varieties and forms. To avoid unnecessary repetition and to reduce the size of the paper, separate and complete description of each variety or form is not included. But the distinguishing characters of every variety and form are mentioned in their appropriate places. It may not, however, be presumed that the material dealt with here is exhaustive and additions will have to be made as new material becomes available.

History of groundnut in India

According to Lieberherr [1928] 'the credit for the introduction of this plant into India belongs to Portuguese Jesuit Fathers who followed Vasco De Gama shortly after his first landing in Malabar Coast in the year 1498. Badami [1930] is of the opinion that groundnut was introduced into India by Magellan expedition. Since there is no word in Sanskrit for groundnut and since South America was discovered about the year 1500, it is most likely that the plant was introduced into India at the earliest in the first half of the sixteenth century. Whoever be the unknown benefactors who first brought this unique plant to this country, the amount of good done is of inestimable value. With the introduction of groundnut as an oilseed in the European markets in 1840, a stimulus for its cultivation appears to have been received. The area under groundnut in Madras which was confined only to the South Arcot district was 4,000 acres in 1850 and then rose up to 20,000 acres in 1870. In 1937-38 the area under groundnut in Madras reached the peak of 4½ million acres. In the beginning, the area was confined to the districts round about South Arcot but later on it extended to other districts as well. In about 1896-97 the area began to fall off and the so called indigenous variety was said to have deteriorated. Messrs. Parry and Co. then introduced the 'Mauritius' form from Mozambique [Benson, 1909]. According to Lieberherr [1928] there was a fall in the area in Bombay also about the same time and the 'indigenous' variety

disappeared from the market. In Bombay, during the period 1904 to 1906 'Big Japan' form was introduced [Kelkar, 1911], which is now commercially known as 'Bombay Bold'. About 1910, the 'Spanish' and the 'Small Japan' bunch forms (light rose and red seeded types) were introduced into Bombay and these were later on extended to South India. In passing, mention may be made of the number of improved varieties and strains which have been recently released for cultivation by the various State Agricultural Departments in India ; three from Madhya Pradesh, five from Bombay, three from Mysore, four from Uttar Pradesh, one from East Punjab, and four from Madras. A short note on the strains under large-scale multiplication and distribution in Madras State is given in Appendix V.

Between 1882 and 1910 the area under groundnut remained more or less stationary both in Madras and Bombay at a total of about 0·4 million acres. In the next five years it doubled itself and between 1913 and 1918 showed a sharp increase from about 1·4 million to 2·3 million acres. During the next five years a fall in the area was witnessed. A very rapid extension, however, took place between 1922 and 1928 when the area rose to over four million acres. Till then the expansion was confined largely to Madras and Bombay. From 1930 onwards, however, a considerable increase in the area occurred in the Indian States, notably in Hyderabad. In 1937, the total all-India area under groundnut reached a record figure of over eight million acres. The introduction of suitable varieties is no less responsible for the very rapid expansion than the improvements in trading facilities and good prices.

The history of groundnut in India has shown, in no small measure, how very important and useful an introduced plant can prove to be, and how necessary it is to give proper trial to it under suitable conditions. If only this had been realised by the people earlier, this extraordinary plant would not have been hibernating in the West Coast for nearly two centuries till it found its way to South Arcot. The history should further stimulate search for more exotic plants that would prove a blessing to this country.

Botanical description of A. hypogæa *Linn.*

It is an annual herb about a foot high. Branching is characteristic. The main axis is erect and rather short. The basal primary branches are longer than those situated higher up the main axis. The basal primaries may be erect, oblique, procumbent, prostrate or training on the ground according to the variety. Stem is pale green tinged with varying grades of purple and rarely without tinge also, herbaceous and somewhat compressed when young, becoming more woody and round with age. Stem is hairy, hairs soft and spreading when young and deciduous at later stages.

Leaves are compound, alternate, stimulate, stipules two, adnate to the base of the petiole upto below their middle, sub-falcate, the free ends tapering and long acuminate. Petiole is jointed and pulvinate where the stipules become free and grooved on the inner side. The groove is ciliate along the margins. Base is semi-amplexicaul.

Leaflets are opposite, sub-sessile in two pairs, situated closely towards the top of the petiole. The upper pair is larger than the lower one. Each leaflet has a short pulvinus at the base. The shape varies from elliptic, obovate to oblong ; margin is entire, ciliate ; base is slightly sub-cordate and the tip is obtuse and shortly mucronate. The colour is pale to dark green. The lower side where the midrib is more prominent is always paler than the upper side. The number of veins varies from 10 to 15 pairs or more. Leaflets exhibit nyctitropic or sleeping movements.

Flowers are sessile and not stalked, usually 3-5 in axillary sub-sessile, bracteate cluster. Bract 1-1½ cm. long, triangular, distinctly long, acuminate, sometimes bifid at the tip, ciliate along the upper margins, pale and membranous below and green towards the tip. Flowers complete, fertile and sterile flowers do not actually exist, bracteate ; bract triangular, similar to the bract of the cluster but smaller about 0·75 to 1·9 cm. long. Bracteoles two, narrow, as long as the bract, membranous, fused into one and tip bilobed each lobe being long, acuminate, green and hairy.

Calyx. Tubular, narrow, 2 to 7 cm. long, sparsely pubescent with white spreading hairs and pale green. Limb of calyx two lobed, anterior linear, posterior ovate, four toothed at the tip, the middle two connate into one.

Corolla. Orange and yellow, papilionaceous, standard sub-orbicular, tip emarginate, deflexed at about 90° above the gibbose, thickened clawlike base. Purple veins radiate upwards from the top of the thick base, rarely the purple colour may be absent. Wings are two, lemon yellow without, pale within, free, somewhat oblong, veined, broader towards the top and short clawed and linear ; tip is obtuse and rounded. Keel petals are two, membranous, pale, united, incurved about the middle, beaked, short clawed, enclosing the staminal sheath. Stamens are 8, monadelphous ; staminodes present or absent and if present the number may be either one or two ; filaments are free above the bend ; anthers are dimorphic, four oblong, three two-celled and one one-celled on short filaments and the other four which are globose and one-celled are on longer filaments. The oblong anthers are adnate and not basifixed.

Ovary. Green, minute, cylindric, sessile, situated at the base of the calyx tube. Ovules usually 2-3 on the ventral suture, green, anatropous ; embryo is straight ; style is long, filiform, slightly displaced towards one side at the top of the ovary, is closely hairy below the stigma which is minute and terminal.

Fruit. An indehiscent, inflated legume, usually sub-cylindric with 1-3 seeds. Pericarp is constricted between the seeds and reticulate without, and hard. The ovary after fertilisation develops into a stalk-like structure called the ' peg ' which penetrates the soil. The ' peg ' grows by the elongation of the ovary base. Seeds are ex-endospermous, round or sub-cylindric ; testa is light rose, rose or red and rarely dark purple or white ; raphe is short near the micropylar end ; cotyledons are fleshy and contain oil ; germination is epigeal. The first pair of branches arises from the axils of cotyledons.

Flowers are invariably self-pollinated. The root system consists of a lone tap root with numerous lateral roots confined mostly to the surface layers of the soil, the roots are covered all over with bacterial nodules. The hypocotyl region

to a length of 3 to 5 cm. below the first pair of branches is provided with short and thin roots.

Varieties and forms

A large number of groundnut varieties and forms are met within the various groundnut growing countries of the world. An extensive collection of these varieties and forms was got together and is being maintained at the Agricultural Research Station, Tindivanam, South Arcot district, Madras State. From a study of these forms extending over nearly 20 years it has been found that a number of these though received under different names, are identical. With a view to distinguishing all the distinct varieties and forms, and group together identical ones and to know the range of variation available for the plant breeder, the present work was undertaken.

The first systematic classification of the groundnut was attempted by Van der Stok [1910]. He divided the forms cultivated by the 'indigenous' people of Java into two main groups, namely, the long duration and the short duration. These groups were said to differ markedly in their growth habit, branching and size and colour of leaflets. The cultivated varieties which mostly belonged to the short duration bunch group were further divided by him into three other groups based on their pod size, kerneled nature, testa colour and shelling percentage.

Badami [1930] has grouped 12 varieties into seven groups, based only on their productivity and not on other characters.

Chevalier [1933] after classifying some of the races and varieties of the groundnut mainly on the basis of pod and seed characters came to the conclusion that classification could be done satisfactorily by an examination of live material. Hayes [1933] has grouped the varieties into ten groups utilizing systematic grading and characters. Luzina [1935] after examining a large collection of 300 specimens from all over the world in the Institute of Plant Industry, Leningrad, says that in spite of the great number of specimens, the collection is poor in varieties and that the want of sufficient knowledge of the biological properties of the available material makes a clear classification of the cultivated species of *A. hypogaea* impossible at present. As a result of preliminary study he distinguishes three basic groups comprising ten types, five in bunch and five in prostrate groups including all the cultivated types.

The characters which are considered to be of sufficient classificatory value by the authors are described here. Minor characters are dealt with separately. A section on economic characters has also been added to make it more useful to the breeder.

Characters of classificatory value

Growth habit. The commonly cultivated forms are normally classified according to their habit of growth into two main groups, viz. spreading (running) and bunch (erect). The spreading type is characterised by the branches spreading on the ground

HABIT OF GROWTH IN GROUNDNUT

Fig. 3. SEMI-SPREADING

Fig. 1. ERECT

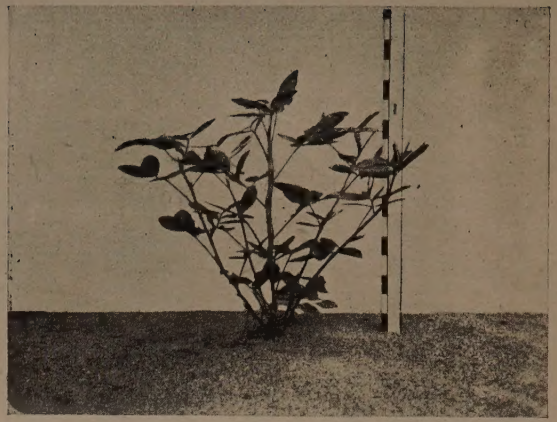


Fig. 2. BUNCH

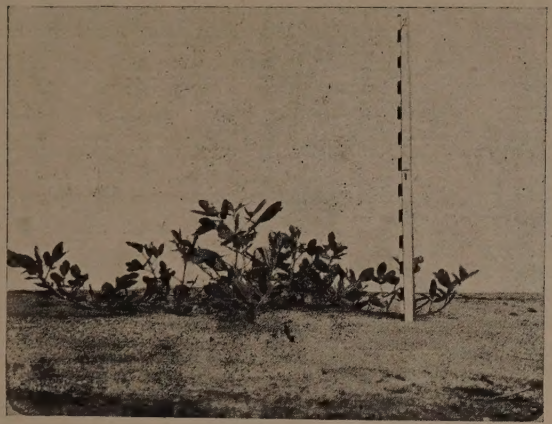


Fig. 4. SPREADING

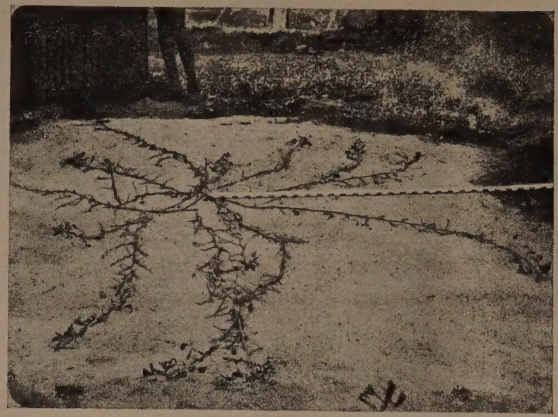
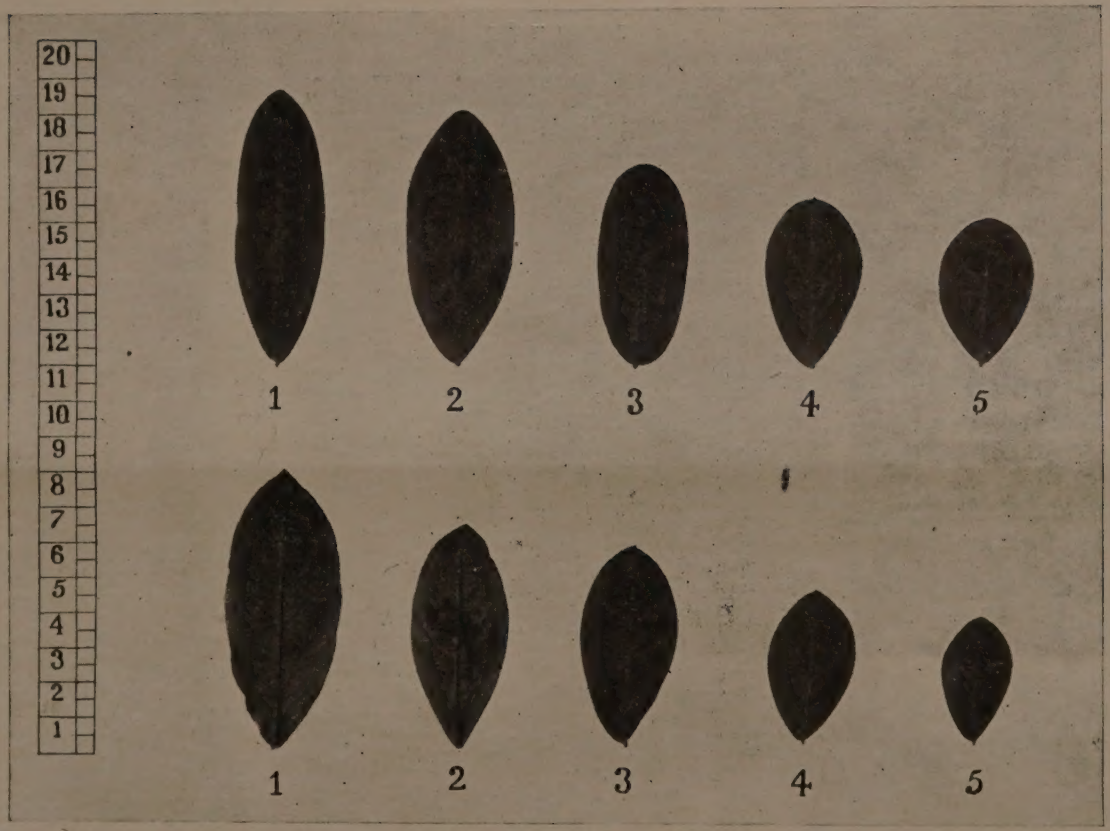


Fig. 5. TRAILING

SHAPE AND SIZE OF LEAFLETS OF GROUNDNUT



Top row :—1. Elliptic 2. Oblong-elliptic 3. Oblong
4. Elliptic-obovate 5. Obovate

Bottom row :—1. Very large 2. Large 3. Medium 4. Small
5. Very small

most of their length with the tips ascending slightly (Plate IV, Fig. 4). The 'Big Japan', 'Mauritius' or the 'Coromandel' are the well-known examples of this form of habit. In the bunch type the branches grow obliquely upwards from the base of the main axis (Plate IV, Fig 2). This habit has been described by some workers as ' erect '. But in this paper the erect habit which is distinct from the bunch has been separately dealt with. The 'Spanish' and 'Small Japan' are some of the bunch forms. The semi-spreading habit is intermediate between the bunch and the spreading. The branches are procumbent or prostrate at first and then distinctly ascending most of their length (Plate IV, Fig 3). The forms coming under this group are rare and, therfore, this form of habit is not well-known. The form 'Native Tanganyika' is a good example of this type. The habit of var. *nambyquarae* approaches the semi-spreading type. According to Sampson [1936] the variety originally introduced into India was of this type. Forms having this habit of growth have also been recorded from French West Africa. In this connection it may be mentioned that this type of habit is of rather frequent occurrence in the progeny of crosses between the bunch and the spreading forms. It may, therefore, be surmised that this habit has perhaps arisen through hybridisation.

Besides these three recognised forms of growth habit, there are two other types evolved by hybridisation. These types have been breeding true for habit. One is an ' erect ' type allied to the bunch, with the branches growing quite erect, almost parallel to the main axis (Plate IV, Fig. 1) and not oblique as in the bunch type. The other is what may be called a ' trailing ' type (Plate IV, Fig. 5) with branches radiating from the centre and trailing on the ground throughout their entire length. These two types may be considered to be extreme limits of habit in the groundnut. It may be mentioned here that some experience is required in classifying these five forms of habit correctly. The classification can best be carried out between six to eight weeks after sowing and that it is essential to sow the seeds at a uniform depth on flat ground instead of in furrows or on ridges.

The spreading habit is caused by two semi-spreading factors which are both dominant to the bunch factor. The segregation in the F_2, showed one bunch to every 15 of the other dominant types. The classification of the 15 dominant types into distinct ' spreadng ' and 'semi-spreading ' groups, however, presented considerable difficulty due to interaction of various factors. This is in agreement with the observations of Badami [1928] that erect is recessive to spreading with a bifactorial difference. Hayes [1933] has, however, reported that the segregation for habit is on the basis of 15 : 1 ratio.

The habit of growth of the groundnut plant influences considerably the agronomic practices. The optimum spacing and the mode of harvest in the groundnut largely depend upon the habit of growth. In the bunch type the pods are formed at the basal nodes of the branches, so that when the plant is pulled out, the pods appear in a cluster round the main axis. This type of habit is very desirable in that maturity of the pods is uniform and harvesting is easy. In the spreading and trailing types the flowers are produced throughout the length of the branches so much so at the time of harvest, the flowers produced later, yield pods which are less mature than

those formed earlier. The bulk of groundnut produce in the Indian market is from the spreading forms.

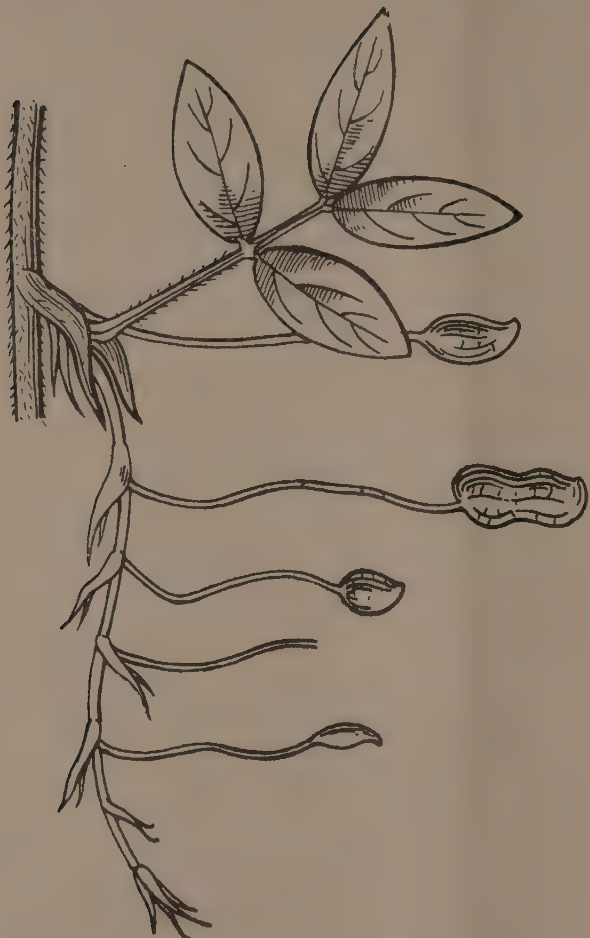
Branching. There are both branching and non-branching types of groundnuts. In the non-branching type secondary and tertiary branches are not met with, but occasionally a small branch may appear at the base of the first pair of primaries (Plate IV). The branching type is characterised by the production of secondary and tertiary branches. In the branched types the number of primary branches is also larger than in the non-branched forms (Plate IV). Whereas most of the bunch forms are non-branched, most of the spreading forms are branched. Patel and others [1936] have shown that branching is dominant over non-branching and is caused by a single gene difference.

Duration. The proper stage for harvest is indicated by the yellowing of the leaves when most of the pods are mature. Naturally, the duration (i.e. the period between the time of sowing to the time of harvest) varies with the conditions of growth or environment. When the same form is grown both under rainfed and irrigated conditions, it usually takes a longer period to attain maturity under irrigation. The difference may extend even up to 30 to 60 days. But under a set of given conditions, different forms exhibit different periods of growth and maturity. The periods of duration recorded herein are for the crop grown under rainfed conditions, and for more or less the same soil obtaining at Tindivanam. The bunch forms usually take 100 to 110 days to mature while the spreading ones from 130 to 150 days. The duration of 'H. G. 1' which is semi-spreading in habit is 120 days. Among the varieties and forms studied so far var. *rasteiro* has the longest duration extending up to five months or more. According to Patel and others [1936] the semi-spreading variety originally grown in Madras took seven months to mature. The bunch forms 'Volete', 'Mac Span' and 'Florida' have the shortest duration of 100 days. In this connection it may be pointed out that the early forms commence flowering early that is between 22nd and 25th day after sowing, while the late forms enter reproductive phase a few days later. Late duration is dominant over early. The F_1 is intermediate in duration and the F_2 segregation is in the ratio of one late, two medium and one early [Patel, *et al.*, 1936].

Leaf. The leaves and leaflets are usually larger in the bunch than in the spreading forms in which the chlorophyll pigment is more intense. Exceptions are found in 'H. G. 1' and 'Akola 10' which have dark green leaves though their habit of growth is not spreading. Usually the large size of the leaf is associated with long petiole and stipules. The variation in the shape and size of leaflets and the number of veins is considerable (Plate V). Var. *nambyquarae* has long narrow leaflets.

Pubescence. Hairs are found on the stem, petioles, stipules, leaf rachis, leaflets and calyx. All the known varieties and forms are hairy and no form is completely glabrous.

Young parts are more hairy than the old from which the hairs drop off. Hayes [1933] mentions four grades of hairiness on the petioles. According to him Sine has few hairs (Grade I) and Java White has many hairs (Grade IV). In the present study only three grades are recognised, 'Gudiyattam Bunch' having many, 'Philippine



Abnormal-elongated axis (var. *gigantea*)

Normal-congested axis (forms of var. *oleifera*)

White' having few and 'Barbados Ceylon' being intermediate. In the var. *asiatica* the hairiness is so thick (felt-like) and distinct from any cultivated variety that it forms a grade by itself.

Three types of hairs are met with in the groundnut forms. The most common is the uniseriate, long spreading type in which the hairs are sparsely arranged. The length of the hair is 1·5 to 2·5 mm. made up of a row of cells. The three or four basal cells are nearly as broad as long, the lowermost cell being the broadest. The terminal cells are three or four in number and much elongated. On account of the disappearance of the adjoining cell walls, the terminal cells appear as one continuous cell. The outer walls of this type of hairs are thickened and the cavity is narrow.

In the second type, the hairs are closely arranged and are much more numerous than the first and always occur in conjunction with the first type. Although similar in shape, the second type can be distinguished from the first by its much reduced length which is $\frac{1}{3}$ to $\frac{1}{4}$ mm. The origin of these two types appears to be the same but the second type seems to result from arrested development.

The third type is quite distinct being green and consists of bulbous based hairs tapering towards the tip. They are rather stiff, bristle-like, long and made up of many layers of cells containing chlorophlasts. These bristles are rather few and occur on stipular sheath of certain groundnut forms as in the 'Valencia Red'. In var. *rasteiro* and var. *nambyquarae* they are found to occur in large numbers on calyx, petioles and stem. But in the spreading forms these bristles are completely absent. Luzina [1935] speaks of glandular pubescence referring to the bulbous based bristles in 'Valencia', *A. rasteiro* and *A. nambuquarae*. He further says that such hairs are never observed in bunch types, other than 'Valencia'. In the very rare type ' Kashgar ' from Chinese Turkestan (synonymous with var. *asiatica*) Luzina speaks of very thick felt-like pubescence on all parts of the plant.

Hairiness is dominant over sparse hairiness and is caused by a single gene difference [Patel, *et al.*, 1936].

Anthocyanin pigment. The presence of purple pigment on the stem in varying intensity is of common occurrence. On the tender developing ' peg ' the pigment is much more pronounced. In ' Philippine White ' a mutant, the pigment is completely absent and the ' peg ' and the branches are quite green. Hayes [1933] has used four grades of purple in his classification but since the gradations of colour are always difficult to be distinguished, these have not been made use of in the present classification. But they are simply mentioned as qualitative characters. The purple pigment in the plant is produced by duplicate genes which give in the F_2, 15:1 ratio. It is suggested that the two factors which produce the rose coloured testa might also produce the purple pigment on the plant [Patel, *et al.*, 1936].

Inflorescence. In all the known groundnut varieties and forms the flowers are one to five, usually three axillary in a sub-sessile cluster. But in the var. *gigantea* (Plate VI) which has been evolved from a cross, the axis of the inflorescence elongates to a length of 10 to 20 cm. in the mature stage and the flowers are five to eight. The character of the elongated inflorescence axis is new to the genus, ***Arachis.***

Flower bud. Size and shape of the mature flower buds about 12 hours prior to anthesis, afford an additional difference between the bunch and the spreading groups. The buds are long, narrow and acuminate in the spreading types while in the bunch types they are rather short, distinctly bulged at the base and the tip is rather blunt and short pointed.

Corolla colour. The standard petal is lemon yellow with orange periphery and has a purple crescent at the base from which radiate purple lines. The wing petals are also lemon yellow, but the keel petals are very pale yellow in colour. Hayes [1933] distinguishes five grades of corolla colour, the intensity increasing from Grade I (Java White) to grade V (Falcon). Even in our collection it has been possible to distinguish five such grades (Plate VII) the depth of colour decreasing from 'Native Tanganyika' (Grade I) to var. *rasteiro* (Grade V). The colour is judged from that of the standard. According to the present classification of corolla colour, most of the spreading forms are of Grade II while most of the bunch forms are of Grade III.

Hayes mentions five gradations of colour of the crescent, the colour being the faintest in 'Philippine White' and most prominent in 'Zaria'. In the present study also five grades of the crescent colour have been made out (Plate VII). 'Native Tanganyika' has a deep purple crescent (Grade I) while it is completely absent in 'Philippine White' (Grade V).

Corolla size. The corolla is larger in the bunch varieties than in the spreading ones, but the difference does not seem to be significant enough to form a distinguishing character.

Opening and fading of flowers. Anthesis occurs by sunrise. The flowers in the bunch forms open a little earlier than the spreading ones. In the spreading forms, the corolla closes completely by 12 noon and the calyx tube bends down by 2 p.m. In the bunch types the closing of the corolla occurs by about 2 p.m. and the calyx tube bends down by 4 p.m. These observations were made in September on a rainfed crop at Tindivanam.

Calyx. The calyx tube is long in certain forms (Gudiyatham Bunch—5 cm.) and short in others (Spanish Bunch or San Jose—1·6 cm.) The calyx tube is usually pale green and with or without a purple tinge. Though the depth of colour varies from form to form the variations are not distinct enough to separate the forms.

Calyx limb. The length of the posterior limb in relation to that of the standard when observed in the open flowers is found to be a distinguishing character. The calyx is about half the length of the standard in the bunch forms. In 'Spanish Bombay' which is semi-spreading the calyx is three-fourth the length of the standard as in the spreading forms.

The mid-rib of the posterior limb is thicker and of darker green than the sides which are paler and more membranous. The colour varies from pale green to green and may be tinged with pink but it is considerably influenced by environment.

Calyx teeth. The posterior lobe of the calyx is made up of four teeth, but as the middle two are more closely united the lobes appears three-toothed. The length of the teeth as seen in the open flower varies from slightly to deeply cut teeth but the

GRADES OF COROLLA COLOUR AND INTENSITY OF PURPLE CRESCENT IN GROUNDNUT VARIETIES AND FORMS

COLOUR OF STANDARD PETAL

Grade I
Native
Tanganyika

Grade II
H. G. 1.

Grade III
Small
Japan

Grade IV
var.
nambyquarae

Grade V
var.
rasteiro

PURPLE CRESCENT ON STANDARD PETAL

Grade I
Native
Tanganyika

Grade II
Gudiyatham
Bunch

Grade III
var.
asiatica

Grade IV
var.
rasteiro

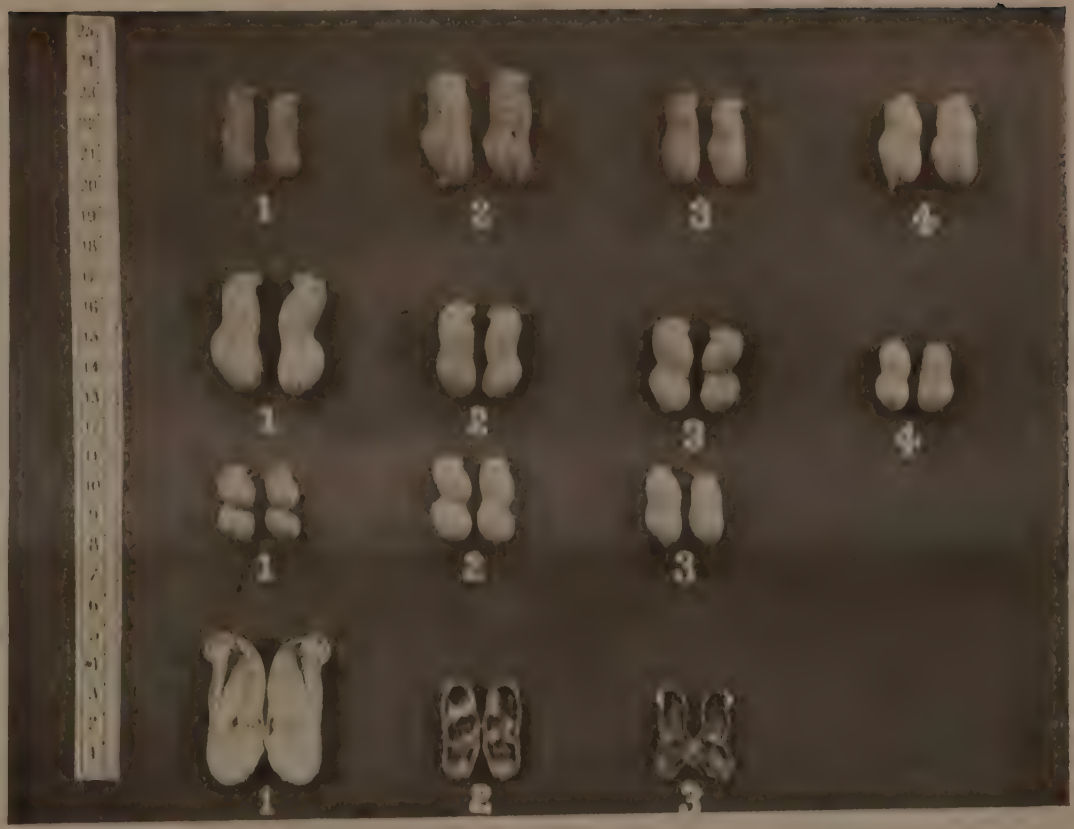
Grade V
Philippine
White

Top row :—Pods

1. Very big (var. *nambyquarae*) 2. Big (var. *rasteiro*)
3. Medium (Saloum) 4. Small (Local Mauritius)
5. Very small (Louga)

Bottom row :—Kernels

1. Very Big (var. *nambyquarae*) 2. Big (var. *rasteiro*)
3. Medium (Saloum) 4. Small (Local Mauritius)
5. Very small (Louga)



Top row :—Reticulation of pods
1. Very prominent (Var. *asiatica*) 2. Prominent (Mauritius Pistache) 3. Distinct (Wild Falcon A)
4. Not distinct (Louga)

2nd row from the top :—Beak of pods
1. Very prominent (Saloum) 2. Prominent (*Gamitam Budda*) 3. Distinct (Small Japan)
4. Not distinct (Louga)

3rd row from the top :—Constriction of pods
1. Deep (MacSpan) 2. Medium (Guidyatham Bunch) 3. Shallow (Bassi)

Bottom row :—Shell thickness
1. Thick (Texas) 2. Medium (Kumayu) 3. Thin (Local Mauritius)

value of this character for classification is limited. Hayes [1933] mentions three grades, viz. short (Spanish Bunch), intermediate (Virginia Bunch) and large (Big Japan).

Hetero-stylism. The stigma usually protrudes above the anthers, but in the forms, 'Small Japan' and 'Coriente-3' the stigma is flush with the stamens.

Pollen. The pollen grains in the dry state measure 50μ × 20μ and are oblong with one deep longitudinal furrow and two shallow ones. When moistened the grains assume a spherical shape and measure 35μ - 50μ in diameter. The exine is minutely pitted and the grains are characterised by three longitudinal grooves, meeting at the base and the top. The germ pores are located in the grooves. The percentage of pollen sterility seems to be very low and is usually below five per cent in the forms of var. *deifera*, var. *nambyquarae* and var. *rasdera*. The pollen grains do not present any distinguishing character among the forms and varieties of *A. hypogaea*.

Pollination. The stigma protrudes above the anthers and is receptive at the time of pollination, but cross pollination does not take place because the stigma is still enclosed in the keel, and self-pollination is the rule in most of the groundnut varieties and forms. However, in certain varieties like var. *nambyquarae* and var. *asiatica* (Kurumani) it so happens that the stigma and the anthers exert out of the keel and remain spread out. And as the stigma is first receptive, there is some chance for cross pollination by means of insects and wind.

Size of the pod. Though the size of the pod is influenced to a certain extent by soil and environmental conditions it affords a distinguishing character. The length of the pod depends usually on the number of seeds in the pod and the length of the seeds. The variation in the size of pods and kernels met with is shown in Plate VIII. The largest pod met with is in var. *nambyquarae* measuring up to 6 cm. × 2 cm. The forms 'Baol' and 'Louga' possess very small pods measuring 1 cm. to 2 cm. × 1 cm. In the present study the size of the pod has been arbitrarily classified into (1) very big, (2) big, (3) medium, (4) small and (5) very small.

Beak of the pods. The base of the style which is subterminal gets displaced towards the dorsal suture by the rapid growth of the tissue at its base and towards the tip of the ventral suture. This gives rise to the beak which is compressed sideways. Though the beak is present in all the varieties, its manifestation varies considerably from 'not distinct' in 'Louga' to 'very prominent' in Saloum. Very prominent, prominent, distinct and not distinct are the grades used in the present classification (Plate IX).

Shape and constriction of the pods. The shape of the pod is cylindrical with oblique ends. The fruit coat or shell follows the contour of the seeds within the pods. The constriction between seeds varies from deep to very shallow even in the pods obtained from a pure line. But the majority conform to a particular grade. When the seeds are placed rather far apart, the constriction is much pronounced. The seeds are, however, usually placed close together end to end, and the constriction is shallow, becoming more distinct or less distinct as the shell is thin or thick. The

less shallow the constriction, the more regular and cylindrical the pod appears. The constriction is deep and pronounced in Mac-Span and shallow in Bassi (Plate IX).

Reticulation of the pods. The reticulate nature of the fruit coat or the outer side of the pod is brought about by the veins running lengthwise from the base of the pod to the stylar end. These veins are connected by short parallel cross nerves. The number of longitudinal veins varies from ten to fifteen. They may be non-distinct or smooth as in some forms of var. *oleifera* or angled and rough as in var. *rasteiro*. The pods of var. *nambyquarae* are described by Patel and others [1936] as striate. Here the longitudinal veins are much pronounced and the cross veins are less distinct presenting a deeply reticulate appearance (Plate IX). *A. sylvestris*, the supposed progenitor of the groundnut, is said to be without reticulation or striation on the fruit coat.

Seed. The number of kernels in the groundnut pod varies from one to five. But in any given form only a particular number say two or three is of most frequent occurrence and the next higher or lower number is much less common. Two-seeded pods are frequently met with in most of the forms. Three-kernelled pods are met with in both the bunch and the spreading forms. The shape of the kernel varies from nearly spherical as in the Spanish types which have usually well filled small pods to cylindrical in the big sized pods. The ends of the seeds which touch each other are flattened unlike the free ends which may be either round or pointed.

The small seeded bunch forms have plump seeds, i.e. the seed is well filled and the seed coat looks quite stretched while in most of the spreading ones the seed coat is slightly puckered or wrinkled and the seeds are not plump. There are some forms which are intermediate between these two groups as in 'Saloum', 'Masumbika' and 'Philippine White'.

The cotyledons are usually creamy white in colour but in var. *rasteiro* they are pale yellow.

Colour of seed coat or testa. The colour of the seed coat of the immature kernel is not fully developed and is generally lighter. There is usually a slight change in the intensity of the colour when the pod is dried after the harvest. The lighter shades of colour, particularly rose, get intensified when the kernels are stored in bottles which are exposed to light. Various workers have therefore described the rose colour as tan, buff or pink. To avoid confusion and to secure uniform standards of observation, the colour obtaining at the time of harvest is alone taken into consideration. The variation in the testa colours met with is shown in Plate X. Most of the groundnut forms have rose coloured kernels. The colour of the testa of the kernels of the 'Philippine White' which is said to be a mutant from 'Philippine Pink' is creamy white or ivory. In 'Small Japan' dark red coloured kernels are met with and in 'Corientes-3' the testa is dark purple.

There are two duplicate factors for the rose colour. The factor for red and the factor for purple are dominant to rose, but the red and the purple factors are expressed only in the presence of rose factors. The purple is dominant to red. The white seed coat colour is recessive to the coloured seed coats [Patel, *et al.*, 1936]. Some of these findings are in agreement with those obtained by the earlier workers.

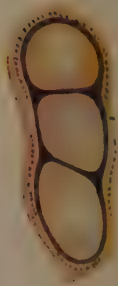
TESTA COLOURS IN GROUNDNUT SEED

1

2

3

4



5

6

7

1. Purple (Corrientes-3)
2. Red (Small Japan)
3. Rose (Saloum)
4. Light Rose (Gudiyatham Bunch)
5. White (Philippine White)
6. White blotched with purple red (var. *rasteiro*)
7. White blotched with purple red (var. *nambyquarae*)

In var. *nambyquarae* and var. *rasteiro* the seed coat is ' white blotched with purple red.' The red is the colour of the testa and white that of the tegmen. The spotted or blotched appearance (Plate X) is due to the incomplete development of the testa or the outer seed coat as mentioned by Stokes and Hull [1930].

Shell thickness. The small pods have usually thinner shell and consequently higher shelling percentage than the large ones. In var. *nambyquarea* and var. *rasteiro* the pericarp or the shell is distinctly soft within.

Economic characters

Economic characters are those which are of agricultural and commercial importance. In groundnut the following characters are considered to be of value either by the farmers or the traders.

(i) Shelling percentage
(ii) Number of kernels per pound
(iii) Natural test weight of pods and kernels
(iv) Oil content
(v) Free fatty acids content
(vi) Depth of pod formation
(vii) Seed dormancy

Shelling percentage. The proportion of kernels to pods by weight is known as the shelling percentage. This character is of importance because in the chief markets where groundnut is purchased by the exporting firms, transactions take place only in the form of kernels. Whatever may be the yield of pods, the cultivator gets paid only on the basis of kernels. So the outturn of kernels per unit weight of pods is of considerable importance. It is governed by a number of factors, viz. thickness of shell, development of the kernel and the constriction of shell between seeds, etc. The thick shelled var. *nambyquarae* and the form 'Texas' have low shelling percentage (65 to 70). The thin shelled forms—' Volete ', ' Spanish 10 ', ' Florida II ', etc. have high shelling percentage (78 to 80). Types with very good development of kernels such as 'Small' Japan, have high shelling percentage (80) while types with poor development as var. *asiatica* give low shelling percentage. Forms with deeper constriction have better shelling than those with shallow constriction.

The produce from an irrigated crop has lower shelling percentage than the produce from a rainfed crop. Apart from the varietal differences, shelling percentage is not influenced by the type of soil but is mostly affected by the seasonal conditions, namely, the distribution of rainfall during the development of the pod. This character is equally varietal and environmental.

Number of kernels per pound. In the cost of cultivation of the groundnut crop ' seeds and sowing ' forms one of the chief items accounting for nearly a quarter of the total. The seed rate for this crop is very high and is dependent on the spacing adopted and the habit of growth of the variety or form. The economic spacing worked out at the Agricultural Research Station, Tindivanam, for a rainfed crop

is 6 in.×6 in. for the bunch type and 9 in.×9 in. for the spreading type. The quantity of seeds to be used per acre depends on the size of the seed and consequently on the number of kernels per unit weight. It is always economical to grow a type with small seeds. As there is considerable variation in the size of seeds, the number of kernels per unit weight (a pound) also exhibits similar variation. Var. *nambyquarae* which has the largest sized kernels has nearly 600 kernels per pound while the form 'Louga' with the smallest seeds has about 1400 kernels per pound. But most of the popular cultivated bunch and spreading forms have 1000 to 1400 kernels to a pound. This character is more varietal than environmental in nature.

Natural test weight of pods and kernels. Natural test weight is the weight per unit volume determined under standardised conditions. It is not always that groundnut is disposed of as kernels. In some interior districts of the State and remote villages where there are no facilities for decorticating the nut, the produce is sold away as pods. But the merchants who purchase the pods have some standard whereby they judge the outturn of kernels. The weight to volume relationship is one such standard. They measure about 60 Madras measures of pods in a gunny bag and weigh it. If the weight exceeds 80 lb. then the quality is said to be good and they expect to recover the normal proportion of kernels. In case it is less than 80 lb. then the quality and shelling percentage are considered low and the price is reduced accordingly. Thus the natural test weight of pods is an important economic character. Any strain distributed from Research Stations should have a high natural test weight if it is to replace the less paying local varieties quickly. A strain (TMV. 3—A.H. 698), a selection from a West African form 'Bassi', the distribution of which has recently been taken up by the Madras Agricultural Department, has a high natural test weight of 1 lb. 7 oz. per Madras measure. The natural test weight depends to a large extent on the size of pods and the degree of development of the kernels inside. Types with small pods have generally high natural test weight of 1 lb. 6 oz. to 1 lb. 8 oz, while types with large pods have a natural test weight of 14 oz. to 1 lb.

Though the normal test weight of kernels is not of great practical utility, it is still useful on occasions in knowing the weight to volume relationship of the kernels. The natural test weight of kernels of the bunch types is comparatively higher (2 lb. 15 oz. to 3 lb.) than those of spreading types (2 lb. 10 oz. to 2 lb. 12 oz.). The natural test weight of kernels is not affected by the seasonal conditions to the same extent as that of the pods. This character is more varietal than environmental.

Oil content. The oil content of kernels is of considerable commercial importance particularly in overseas markets where groundnut kernels are valued mainly on the basis of their oil content. Groundnut varieties and forms exhibit variation in the oil content. It is to a large extent influenced by the degree of maturity of the kernels and also the distribution of rainfall during the development of the pod in the crop. It is only when the kernels are well developed that the maximum oil content is obtained. Thus harvesting the crop even a week in advance of complete maturity affects the oil content of kernels to the extent of five per cent as shown by Patel and Seshadri [1934]. Therefore, the crop should be harvested at the correct stage when

most of the pods are well developed. Low and deficient rainfall at the time of maturity of the pods affects the oil content of kernels to a large extent. Among the collection of varieties and forms maintained at the Agricultural Research Station, Tindivanam, var. *nambyquarae* has the lowest oil content of 46 per cent while Vir-Jinia Mauritius has the maximum oil content of 52 per cent. This character is more environmental than varietal.

Free fatty acids content. The quality of groundnut is judged in the market by the amount of free fatty acids in its oil contents. In trade, certain minimum percentage (2·5) of free fatty acids is allowed. For produce having free fatty acids above this limit, the value is correspondingly reduced. The amount of free fatty acids is governed by the following factors, viz. (i) the stage of harvest of the crop, (ii) drying given to the produce after harvest (iii) mode of decortication and (iv) subsequent storage of kernels.

In some places the produce is marketed before it is properly dried. Such a produce when stored develops heat as a result of which the free fatty acids content of the oil in the kernels increases. In the districts of South Arcot, where hand-shelling is in vogue, the produce is shelled by beating with sticks. To facilitate easy decortication the produce is wetted before beating. By this process the kernels inside also get moistened which on subsequent storage develop high free fatty acids content. The exporting firms that handle large quantities during the season also sometimes fail to dry the produce thoroughly before shipment. During transport fermentation sets in so that when the shipment reaches the destination, the free fatty acids content considerably increases. Harvesting at the correct stage, properly drying the produce before storage, machine shelling and thorough drying of kernels before shipment should keep the free fatty acids content at the minimum. Free fatty acids content is purely governed by environment.

Depth of pod formation. This character is of much economic value. Where the pods develop deep in the soil, harvesting becomes difficult and consequently harvesting charges mount up. If the pods develop too near the surface of the soil, there is the danger of the pods being eaten away by birds, rats and jackals. Though some variation in the depth of pod formation is observed in the same variety or form it may be considered to a distinct character as difference in mean values between the varieties or forms are rather considerable. The maximum depth is met with in var. *asiatica* (3·9 cm.) and the minimum depth in ' Montoco seros 7' (1·46 cm.). Among the bunch types, the differences in the depth of pod development are not so much as in the spreading ones.

In this connection, it may be interesting to mention that TMV.-3 (A.H. 698) strain of groundnut under large-scale distribution in Madras State, is appreciated for its shallow pod formation because harvesting is comparatively easy in this strain.

Seed dormancy. Seed dormancy is an economic character in groundnut as seeds of non-dormant types on receipt of rains at harvest time sprout in the field causing considerable loss of produce as in Pollachi and Guntur tracts of the Madras State. On the other hand, seeds of dormant types harvested in December cannot be used for sowing in February under irrigation. Dormancy studies carried out at the

Agricultural Research Station, Tindivanam, show that the bunch forms have non-dormant seeds while the spreading forms have dormant seeds. It is also found that bunch forms can be used for seed purposes about ten days after harvest as 90 per cent of the seeds germinate after a week's drying. In the case of the spreading forms the seeds can be used for sowing only after about $2\frac{1}{2}$ months, as these require a resting period of about 2 to $2\frac{1}{2}$ months. The differences between the bunch forms are small though significant. The form ' Small Japan ' has the longest dormancy among the bunch forms. Unlike in the bunch forms, marked differences are noticed between the spreading forms. 'Native Tanganyika ' has shorter period of dormancy than ' Saloum ', ' Texas' and others. ' Local Mauritius ' is intermediate between these two groups.

The inheritance of seed dormancy was observed in a few forms and their hybrid progenies. Seeds of F_1 progenies are found to be intermediate between the two parents while the F_2 segregation show great variability indicating thereby that multiple genes may be responsible for the expression of this character.

Characters of groups and sub-groups

Based on the chief morphological and agronomic characters, all the available varieties and forms have been grounded into seven main groups and twenty-three sub-groups as detailed in the table of classification (Appendix III). The first four groups, viz. erect, bunch, semi-spreading and spreading, comprise forms of var. *oleifera*.

1. *Erect group.* The type described in this paper as *Arachis hypogaea, forma erecta* is the only representative of this group. This type marks one extreme in the habit of growth of groundnut, in that it has its branches growing almost parallel to the main axis so that the plant presents an erect cylindrical appearance. It has a short stature with small dark green leaves. Pods are tiny, and are one to three-seeded. The shell is very thin, with a shelling percentage of 72·5. The oil content is 50 per cent.

This type was evolved from a cross between ' Spanish 10 ' (bunch) and ' N. G. 1 ' (semi-spreading) forms. It has been breeding true to all the characters of the type.

2. *Bunch group.* The bunch group has been divided into eight sub-groups based on the colour of the seed coat, the size of the pods and the number of kernels in the pods.

(i) *The Spanish sub-group.* The Spanish types are of much economic importance, met with in most parts of India on account of their short duration (105 days) and high shelling percentage (77·0). They are characterised by the bunch habit of growth, having four or five primaries and rarely one or two secondary branches. The pods are found close to the base of the plant and this facilitates easy harvest. The small size of the seed is another desirable character because the seed rate for such seeds will be low.

The leaflets are large and light green in colour, pods are small, one to two-seeded ; beak is distinct ; shell is distinctly reticulate, very thin ; the seeds are plump and light rose in colour.

The popular form of South India, namely 'Gudiyatham Bunch' is a type of this sub-group. It is extensively cultivated in the districts of Guntur, Kurnool, North Arcot and Ramanathapuram and covers about ten per cent of the groundnut area in the State.

Commercially this form is known as the ' Peanut ' or ' Khandesh '. The other members of this group are 'Valencia White', 'Reconquista 6' and 'San Jose' (Philippine). In 'Valencia White' the reticulation of pods is not so distinct as in the other two.

Though Luzina mentions that the oil percentage of this group as determined with his material raised in the U. S. S. R. is as high as 67, under South Indian conditions the maximum as determined by ether extraction is only about 49 per cent. This lower percentage is perhaps due to the soil and climatic conditions obtaining in South India.

(ii) *The Volete sub-group.* This sub-group is closely allied to the Spanish mentioned above but differs from it in the following characters, viz. (1) the duration in this group is earlier by about a week, (2) the pods are a little smaller, the constriction deeper and the beak of pods less distinct, (3) shelling percentage is slightly higher than that of the Spanish types (78). The thinnest shell is found in this group. The type of this sub-group is 'Volete' which has rather stunted growth. The other members are 'Spanish 10', 'Mac Span', 'Casilda 5', 'Florida II, III and IV'. This sub-group will be of much importance in breeding economic types.

This nearly corresponds to the one described by Luzina as the ' Manchurian type '.

(iii) *The Java sub-group.* The members of this sub-group have a much better growth than the Spanish, the stem being much thicker and the leaves larger. The duration is longer than in the Spanish by about a week. The pods are characterised by their medium size and one to three-seeded (three-seeded being occasional) nature. The pods have distinct beak and reticulation. The shell is of medium thickness and therefore the shelling percentage is only 72 to 74. The kernels are also much larger in size. The oil content of kernels is slightly higher than that of the Spanish group being about 48 to 52 per cent.

The type of this sub-group is Java-2. The other members are : 'North Carolina' 'Peanut', 'Java-1, 3-4 and 5', 'Spanish Philippine', 'Improved Spanish', 'Improved Spanish-2 B' and 'Akola 24'.

Under this may be included 'Corientes-1' with small, one to four-seeded pods and 'Tennessee White' and 'Cordoba-2' with medium, one to four-seeded pods, the four-seeded pod being only occasional.

(iv) *The Valencia sub-group.* The types of this sub-group have marked vegetative growth which distinguishes them from all other bunch types. The duration is about 110 days. Another character is the well developed anthocyanin pigment on the stem even in the early stage of their growth. The colour of the leaflets is of

deeper green than that of the Spanish which is light green. The pods are of medium size, one to four-seeded and of somewhat beaded appearance. The veins of pods are not distinct and the pod is smooth, and the shell is of medium thickness so that the shelling percentage is low (71 to 73). The kernels are oblong, dark red in colour and well developed. The oil content of kernels is 47 to 48 per cent. The members of this sub-group are 'Valencia Peanut', 'Kumavu', 'Bunch Mozambique', 'Spanish Bunch' (Salisbury), 'Virginia Bunch' (Tanganyika), 'Tennessee Red', 'Cordoba-4', and 'Monteco Seros-7 and 8'. 'Valencia Peanut' has distinct veins and the shallow to medium constriction does not give the beaded appearance. 'Kumavu' is the type of this sub-group.

(v) *The Small Japan sub-group.* This sub-group is represented by one type, namely 'Small Japan', and is allied to the Valencia sub-group, but the leaflets are of a pale green colour. The pods are also smaller, very well filled and one to two-seeded. The veins and beak are more distinct and the shell is thin and the shelling percentage is about 79. The oil content of the kernels is also high being 50 per cent. This type therefore affords excellent material for selection and breeding, though the red colour of the seed coat is not quite desirable.

This type is known in commerce as ' Red Pollachi ', ' Red Natal ' and 'Lal Boria' in Bombay and is grown mostly in Pollachi *taluka* of the Coimbatore district and parts of Madurai and Ramanathapuram districts in Madras State.

(vi) *Akola 10 sub-group.* This is characterised by the bunch habit of growth with good branching and dark green, small leaves and slender stem. The pods are one to three-seeded and large-sized. Shell is thick and the shelling percentage is low. The oil content is 48·3 per cent.

This sub-group is represented by the two forms from Madhya Pradesh 'Akola-10' and 'Buldhana'.

(vii) *Corientes-3 sub-group.* Corientes-3 is quite distinct in having a stunted growth and a unique seed-coat colour, viz. dark purple. Pods are medium sized and one to four-seeded. Shell is medium and the shelling percentage is low (74 per cent). The percentage of oil in kernels is 48.

(viii) *Porte Alegre sub-group.* 'Porte Alegre' is the only member of the sub-group. In this form the seed coat is dark purple as in 'Corientes-3'. It is also unique in having large sized, smooth veined, one to four-seeded pods and a strikingly robust vegetative growth. The anthocyanin pigment on the vegetative parts is more pronounced than in the other forms.

3. *The semi-spreading group.* The growth habit of the forms of this group is intermediate between that of the bunch and spreading groups and is characterised by the peculiar growth of the branches which are at first spreading and then ascending, giving a characteristic somewhat rounded shape to the plant. There are three sub-groups.

(i) *Gumitam Budda sub-group.* This sub-group is represented by a single form known as ' Gumitam Budda ' collected from Kurnool district of the State. The duration is long, 135 days. The stem is thin. Leaflets are small and dark green.

Pods are small and one to two-seeded ; beak is prominent and veins are distinct. Shell is very thin and shelling percentage is high (76 per cent). Oil content of kernel is 52 per cent.

(ii) *The 'Spanish Bombay' sub-group.* The only representative of the sub-group is 'Spanish Bombay'. This is of medium duration (120 days). The stem is of medium thickness and the leaflets are small and dark green in colour. Pods are medium sized, one to two-seeded. The beak and veins are distinct and the shell is thin. The shelling percentage is 75. The oil content of kernels is 51 per cent.

This type approaches Luzina's ' African Type ' except for the duration which under the U. S. S. R. conditions is reported to extend to 180 days.

(iii) *The Native Tanganyika sub-group.* The leaflets of the forms coming under this group are small and dark green in colour. Pods are medium sized, one to three-seeded. The shell of the pod is of medium thickness and the shelling percentage is 74 to 75. The oil content is 50 per cent.

In this sub-group are included 'H. G. 1', 'Native Tanganyika' and 'Virginia White' Bunch. 'H. G. 1' has more arrested growth than the other two. Its branches are more straight and erect and comparatively thinner and the duration is shorter by a week.

'Virginia Bunch' (Salisbury) is closely related to the Native Tanganyika sub-group except for its short duration of 135 days and one to three-seeded, large pods with thick shell. The shelling percentage is 71. Oil content of kernels is 48 per cent.

4. *Spreading or the Runner group.* The spreading constitutes an important group comprising of seven sub-groups, viz. (i) 'Louga', (ii) 'Wild Falcon', (iii) 'Local Mauritius', (iv) 'Bassi-Saloum', (v) 'Big Japan or Madagascar', (vi) 'Texas' or 'Virginia Running Peanut' and (vii) 'Philippine White'. To this group belong a number of economic forms extensively cultivated.

(i) *Louga sub-group.* Among the spreading forms, the Louga has the smallest pod (2·4 cm. $\times$ 1·0 cm.) and with one to two seeds, very thin shelled, well filled, beakless with very feeble reticulation. The seeds are nearly spherical. The duration is 140 days. Shelling percentage is 78. The oil-content of kernels is 50 per cent. The form called Baol appears to be identical with this.

(ii) *The Wild Falcon sub-groups.* The 'Wild Falcon' A and B are the only two members of this sub-group. The duration is less by about a week than in the Louga group. The pods are slightly larger, one to three-seeded, the three-seeded being rare. Veins and beak are more distinct. The beak end is more recurved than in other forms. The shelling percentage is 77. The oil content of kernels is 50 to 52 per cent.

(iii) *The Local Mauritius sub-group.* The type ' Local Mauritius ' has small, one to two-seeded pods with prominent beak and distinct veins. The shell is very thin and the shelling percentage is 78 to 80. This is extensively cultivated in South India and goes by various names. About 86 per cent of the groundnut area in

Madras State is under this form. The so called forms Sogathur, Mozambique Mauritius and Gooty are identical with ' Local Mauritius '. The duration is 135 days. The oil content of kernels is 49 to 50 per cent. It is one of the well and long known varieties of South India. This is commercially known as ' Coromandel ', ' Mauritius ' or ' Mozambique '. This forms the bulk of the kernels exported (94 per cent) from Madras.

(iv) *The Saloum-Bassi sub-group.* The Saloum-Bassi sub-group is important in that it has been extensively distributed by the Department of Agriculture, Madras.

The Saloum sub-group. 'Mauritius Pistache' and 'Virginia Mauritius' come under this sub-group. The duration is 135 days. The leaflets are small and dark green in colour. The stem is of medium thickness. The pods are of medium size, one to three-seeded, the three-seeded being occasional. Shell is of medium thickness. Shelling percentage is 72 to 77. Oil content of kernels is high the range being 50 to 52 per cent. 'Virginia Mauritius' has thin shell and higher shelling percentage.

The Bassi sub-group. Forms 'Bassi', 'Zaria', 'Philippine Pink' and 'Gambia' are included in this sub-group. The vegetative characters are similar to those of Saloum. The pods are smaller than in 'Saloum', one to three-seeded, the three-seeded being occasional. The beak end is rounded. Shell is thin and constriction between seeds is shallow. Reticulation is distinct. Shelling percentage is 76 to 77. Oil content of kernels is 49 to 51 per cent. Of these four types, the first two, namely 'Bassi' and 'Zaria', have a longer duration with a higher oil content while 'Philippine Pink' and 'Gambia' are of shorter duration (135 days). In 'Bassi' the kernels are more rounded than in others.

(v) *The Big Japan sub-group.* This sub-group comprises the largest number of cultivated forms passing under different local names. All of them have one to three-seeded, medium sized pods. The shell is of medium thickness and the shelling percentage is 74 to 75. The reticulation of the pod is not distinct. The oil content of kernels is 49 to 51 per cent. The type of this sub-group is 'Big Japan', 'Kalahasti', 'Tatas', 'Virginia Runner', 'Carolina', 'Chiba 63' and 'Chiba 73', 'Transvaal', West African, Madagascar, Barbados Ceylon, Rufisque Senegal, Senegal and Local Pondicherry are the other forms of this sub-group.

Some of these names are merely synonyms for the same type. The distinguishing characters of these forms are given in the Key (Appendix IV).

(vi) *Texas sub-group.* The members of this sub-group are characterised by their rather feeble branching as compared with the Big Japan sub-group. They are also shorter in duration by about a week or 10 days. Leaflets are slightly larger and the stem is thicker. Pods are large sized, one to three-seeded, the three-seeded being occasional. The pods have prominent beak but the veins are not quite distinct. Shell is thick and the shelling percentage is 71 to 72. The oil content of kernels is 48 per cent in all the forms except Mauritius Virgini which has a higher oil content of 50 per cent.

Among the spreading forms this group has the largest sized pods and seeds. Forms Texas, Virginia Running Peanut, Rangoon, Mauritius Virgini, Jumbo Runner and Masumbika belong to this sub-group.

(vii) *The Philippine White sub-group.* This is represented by a single type, viz. 'Philippine White'. Though in most characters it approaches the Big Japan sub-group, it is unique in that there is not even a trace of anthocyanin pigment in any part of the plant unlike in other forms. The important characteristic is the colour of the seed coat which is creamy or white. This type is said to be a mutant from 'Philippine Pink'.

This is of great importance in genetic work in the study of inheritance of colour characters.

5. *Trailing group.* While the erect type as has already been mentioned has one extreme habit of growth, the trailing type marks the other extreme and is characterised by very long trailing branches which are quite prostrate on the ground and reaching a length of 5 ft. to 6 ft. at times and producing numerous flowers and pegs. Leaflets are large as in bunch types. The inflorescence unlike in any other groundnut form has much elongated axis. Pods are small, one to two-seeded, with prominent beak, and reticulation is not distinct. Shell is very thin and shelling percentage is 76. Oil content of kernels is 50 per cent.

This is represented by var. *gigantea* evolved from a cross between Gudiyatham Bunch (Bunch) and Madagascar (spreading) forms.

6. *The nambyquarae-rasteiro group.* This group consists of the so called species *A. nambyquarae* and *A. rasteiro.* Their status as species has already been discussed in the beginning and now they are taken to be distinct botanical varieties under the species *Arachis hypogaea* Linn. These two are not cultivated on a commercial scale but they are quite distinct from any other cultivated form of *A. hypogaea*; they are easily distinguished by their ruptured seed coat, blotched with red and white. The pods are very large and prominently veined. The shell is thick. Var. *nambyquarae* has a shelling percentage of 68 and an oil content of 46 per cent. Var. *rasteiro* has a higher shelling outturn and oil content.

These varieties form very interesting material for breeding and genetic work.

7. *The asiatica group.* This is represented by 'Kurumani' or 'indigenous' type of South India with semispreading habit of growth here called as var. *asiatica.* It is said that this variety was originally cultivated but is now rather rare, being occasionally met with in parts of Mysore and elsewhere. It is distinct from all other types in having very dense pubescence and very profuse branching with many primaries, secondaries and tertiaries. The pegs are long and the pods develop deep in the soil. The pods are usually one to three seeded with occasional four or five seeded ones; they are also characterised by very prominent beak and veins. Though the shell is thin, the shelling percentage is not high (only 73 per cent) owing to the poor development of kernels. The oil content is 49 per cent.

Though the duration is very long (5 to 6 months) the yield is comparatively poor and not uniform. This type can be used in breeding in consideration of its profuse branching habit.

This appears to be identical with the 'Kashgar' type described by Luzina [1935] and *A. asiatica* of Loureiro [1790].

Summary

The groundnut is an important money and food crop of India, and India holds a unique position in the production and trade of groundnut in the world market.

Most probably the country of origin of groundnut is Brazil in South America where all the allied species are found in a wild state. Some thirteen species of *Arachis* have been described by botanists. Of these, six only are considered (Chevalier) to be distinct. All the cultivated forms belong to the species ***hypogaea*** which comprises five distinct botanical varieties, namely var. *oleifera*, var. *nambyquarae*, var. *rasteiro*, var. *asiatica* and var. *gigantea*. Though var. *nambyquarae*, var. *rasteiro* and var. *asiatica* and var. *oleifera* have been variously described as species, sub-species or types by different workers, they are for the sake of uniformity here recognised only as botanical varieties. And all the cultivated forms of groundnut are included under var. *oleifera*.

The history of groundnut in India is interesting. Though introduced first into the West Coast of India in the sixteenth century, probably by Portuguese Fathers, it had been hibernating there for about three centuries. It found its way into the East Coast about the middle of the ninteenth century and came into prominance when its importance was recognised by the cultivators about the end of that century. The area under groundnut in India (South Arcot) in 1850 was only 4,000 acres and it is now about 10 million acres with an annual production of 3·5 million tons (unshelled nuts).

The groundnut has now become a crop of world wide importance and many forms (so called varieties) are known in various countries. Many of these forms were obtained and have been studied at the Groundnut Research Station, Tindivanam (South Arcot) during the last two decades, and much valuable information on their morphological and economic characters has been obtained. These are described and their range of variation indicated. Attempts are made in this paper to classify the collection comprising 85 varieties and forms. The study has revealed that many of these are synonymous and 40 distinct varieties and forms are recognised here and these are grouped into seven main groups and 22 sub-groups based on their morphological and economic characters. An artificial key to help in their identification is appended.

It is hoped that the present work will clarify the position of the different forms and varieties, and help the breeder in his programme of selection and hybridisation.

The authors, however, do not claim that the work is complete and new material will be incorporated as it becomes available.

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APPEN

Non-measurable characters of typical

Name of variety of form	Habit	Leaf colour	Stem pigment	Colour of standard	Intensity of crescent on standard	Testa colour
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Forms under Arachis hypogaea *var.* oleifera						
1. Form erecta	Erect	Dk. Gr.	V. Sl. P.	II	II	Rose
2. Gudiyatham Bunch	Bunch	Lt. Gr.	V. Sl. P.	II	II	Light rose
3. Small Japan	Bunch	P. Gr.	Sl. P.	III	II	Red
4. Volete	Bunch	Lt. Gr.	V. Sl. P.	II	III	Light rose
5. Kumaun	Bunch	Green	P.	III	II	Red
6. Macspan	Bunch	Lt. Gr.	V. Sl. P.	III	III	Light rose
7. Java 1	Bunch	Green	Sl. P.	III	II	Light rose
8. Java 2	Bunch	Green	Sl. P.	III	II	Light rose
9. Valencia Peanut	Bunch	Green	P.	III	I	Red
10. Spanish Bunch (Salisbury)	Bunch	Green	P.	III	I	Red
11. Tennessee White	Bunch	Green	V. Sl. P.	III	III	Light rose
12. Corientes 1	Bunch	Lt. Gr.	V. Sl. P.	III	III	Light rose
13. Corientes 3	Bunch	Green	D.P.	IV	II	Dark purple
14. Cordoba 2	Bunch	Green	P.	II	II	Light rose
15. Casilda 5	Bunch	Lt. Gr.	V. Sl. P.	II	II	Light rose
16. Akola 24	Bunch	Green	V. Sl. P.	II	II	Light rose
17. Porte Alegre	Bunch	Green	D. P.	V	I	Dark purple
18. Akola 10	Bunch	Dk. Gr.	V. Sl. P.	II	II	Rose
19. H.G. 1	Semi-spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
20. Spanish Bombay	Semi-spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
21. Native Tanganyika	Semi-spreading	Dk. Gr.	V. Sl. P.	I	I	Rose
22. Virginia Bunch (Salisbury)	Semi-spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
23. Virginia White Bunch	Semi-spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
24. Gumitam Budda	Semi-spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
25. Local Mauritius	Spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
26. Texas	Spreading	Dk. Gr.	V. Sl. P.	I	I	Rose
27. Carolina	Spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
28. Big Japan	Spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
29. Mauritius Pistache	Spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
30. Virginia Mauritius	Spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
31. Saloum	Spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
32. Louga	Spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
33. Bassi	Spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
34. Wild Falcon A	Spreading	Dk. Gr.	V. Sl. P.	II	II	Rose
35. Philippine White	Spreading	Dk. Gr.	Green	II	V	White
36. Masumbika	Spreading	Dk. Gr.	Sl. P.	II	I	Rose
Other varieties of Arachis hypogaea						
37. *Karumani* (var. *asiatica*)	Semi-spreading	Green	P.	III	III	Rose
38. Var. *namby quarae*	Semi-spreading	P. Gr.	V. Sl. P.	III	IV	Red (ruptured testa)
39. Var. *rasteiro*	Spreading	Dk. Gr.	V. Sl. P.	IV	V	Red (ruptured testa)
40. var. *gigantea*	Trailing	Green	Sl. P.	I	I	Rose

References

1. *Leaf Colour*
   - Lt. Gr. . . . Light green
   - Dk. Gr. . . . . Dark green

2. *Stem pigment*
   - V. Sl. P. . . . Very slight purple
   - Sl. P. . . . Slight purple
   - P. . . . Purple
   - D.P. . . . . Deep purple

3. *Colour of standard :* Grades I to V . . . See Plate VII

4. *Intensity of crescent :* Grades I to V . . . See Plate VII

DIX I.

groundnut varieties and forms

Pods						
Kerneled nature	Size	Beak	Veins	Constriction	Shell thickness	Remarks (other distinguishing features)
(8)	(9)	(10)	(11)	(12)	(13)	(14)
Forms under Arachis hypogaea *var.* oleifera						
1—3	Tiny	Not distinct	Not distinct	Shallow	Very thin	
1—2	Small	Distinct	Distinct	Shallow-Medium	Very thin	
1—2	Small	Distinct	Distinct	Shallow-Medium	Thin	
1—2	Very small	Not distinct	Distinct	Medium-deep	Very thin	Stunted growth
1—4	Medium	Distinct	Not distinct	Shallow (beaded appearance)	Medium	
1—2	Very small	Not distinct	Distinct	Medium-deep	Very thin	
1—3 (3 occasional)	Medium	Distinct	Distinct	Medium-deep	Medium	Leaflets large
1—3 (3 occasional)	Medium	Distinct	Distinct	Medium-deep	Medium	Leaflets very large
1—4	Medium	Distinct	Distinct	Shallow-Medium	Medium	
1—4	Medium	Prominent	Not distinct	Shallow (beaded appearance)	Medium	Main axis long
1—4	Medium	Distinct	Distinct	Shallow-Medium	Medium	
1—4	Small	Prominent	Distinct	Shallow-deep	Medium	
1—4	Medium	Prominent	Not distinct	Shallow-Medium	Medium	Stunted growth
1—4	Medium	Distinct	Not distinct	Shallow (beaded appearance)	Medium	
1—2	Very small	Not distinct	Distinct	Shallow-Medium	Very Thin	
1—3 (3 occassional)	Medium	Distinct	Distinct	Medium-deep	Medium	Beak and veins not so distinct as Java 2.
1—4	Big	Not distinct	Not distinct (smooth)	Shallow-Medium	Medium	Plant robust
1—3	Big	Prominent	Not distinct	Shallow-Medium	Thick	
1—3	Medium	Prominent	Not distinct	Shallow-Medium	Medium	Plant stunted and branches more erect
1—2	Medium	Distinct	Distinct	Shallow	Thin	
1—3	Medium	Prominent	Not distinct	Shallow-Medium	Medium	Plant robust
1—3	Big	Distinct	Distinct	Shallow-Medium	Thick	
1—3 (3 Occassional)	Medium	Distinct	Not distinct	Shallow	Medium	
1—2	Small	Prominent	Distinct	Shallow-Medium	Very thin	
1—2	Small	Prominent	Distinct	Shallow-Medium	Very thin	
1—3 (3 occassional)	Big	Prominent	Not distinct	Shallow-Medium	Thick	
1—3	Medium	Prominent	Not distinct	Shallow-Medium	Medium	
1—3	Medium	Prominent	Not distinct	Shallow-Medium	Medium	
1—3 (3 occassional)	Medium	Prominent	Prominent	Shallow-Medium	Thin	Beak not so prominent as in Carolina.
1—3 (3 occassional)	Medium	Distinct	Distinct	Shallow-Medium	Thin	
1—3 (3 occassional)	Medium	Prominent	Not distinct	Shallow	Medium	Kernels somewhat plump.
1—2	Very Small	Not distinct (rounded)	Not distinct	Shallow-Medium	Very thin	
1—3 (3 occassional)	Small	Not distinct (rounded)	Distinct	Shallow	Thin	
1—3 (3 rare)	Very small	Distinct	Distinct	Shallow	Very Thin	Beak end recurved
1—3	Medium	Prominent	Not distinct	Shallow-Medium	Medium	Devoid of purple pigment throughout Plant robust Kernels somewhat plump.
1—3	Big	Prominent	Distinct	Shallow-Medium	Thick	
Other varieties of Arachis hypogasa						
1—4	Small	Very prominent	Very prominent	Shallow (beaded appearance)	Thin	Highly pubescent
1—2	Very big	Very prominent	Very prominent	Shallow-Medium	Thick	
1—2	Big	Distinct	Prominent	Shallow	Thick	
1—2	Small	Prominent	Not distinct	Medium	Very Thin	Plant robust inflorescence elongated.

APPENDIX II

Measurable characters of typical groundnut varieties and forms

Name of variety or form	Germination capacity	Duration in days	Average acre yield of pods in lb.	Shelling percentage	Oil percentage	Number of kernels per lb.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Forms under Arachis hypogaea *var.* oleifera						
1. Form erecta	..	..	1,041	72·5	50·1	2,440
2. Gudiyatham Bunch	96·9	105	1,242	76·7	48·5	1,365
3. Small Japan	95·8	110	1,112	79·3	49·0	1,209
4. Volete	92·3	100	1,274	77·3	48·9	1,371
5. Kumavu	92·2	110	1,429	72·9	46·8	1,053
6. Macspan	93·4	100	1,209	76·6	48·6	1,348
7. Java 1	94·4	110	1,180	74·3	49·3	1,044
8. Java 2	92·6	110	1,217	73·1	48·9	975
9. Valencia Peanut	92·2	105	1,124	73·0	47·3	1,120
10. Spanish Bunch (Salisbury)	94·5	110	1,243	71·9	49·0	1,047
11. Tennessee White	95·3	110	1,246	74·2	49·0	1,099
12. Corientes 1	97·3	105	1,097	75·5	50·4	1,306
13. Corientes 3	94·2	105	877	74·3	47·9	1,213
14. Cordoba 2	89·6	105	1,043	73·8	47·6	1,094
15. Casilda 5	89·3	100	1,245	77·0	48·8	1,383
16. Akola 24	93·7	110	1,222	74·6	48·7	1,044
17. Porte Alegre	93·1	110	1,028	73·4	48·1	1,141
18. Akola 10	89·0	120	588	67·1	48·3	655
19. H. G. 1	91·5	120	1,151	71·7	49·2	1,043
20. Spanish Bombay	94·8	120	1,400	75·2	51·3	1,012
21. Native Tanganyika	86·7	130	1,452	74·2	50·6	855
22. Virginia Bunch (Salisbury)	76·1	125	983	71·1	48·0	655
23. Virginia White Bunch	81·0	135	1,302	75·0	50·3	815
24. Gumitam Budda	89·3	135	1,603	76·2	52·0	1,113
25. Local Mauritius	81·8	135	1,271	78·4	49·3	1,183
26. Texas	73·6	130	1,036	72·4	49·9	707
27. Carolina	76·0	135	1,425	75·0	50·3	1,013
28. Big Japan	88·2	135	1,518	74·4	51·0	1,026
29. Mauritius Pistache	83·2	135	1,343	74·9	51·6	992
30. Virginia Mauritius	81·5	135	1,478	77·0	52·0	970
31. Saloum	87·8	135	1,583	72·7	50·7	960
32. Louga	86·5	140	1,305	77·5	49·8	1,409
33. Bassi	88·9	140	1,447	75·7	50·8	1,092
34. Wild Falcon A	86·5	135	1,455	76·7	51·8	1,262
35. Philippine White	83·0	135	1,284	73·4	49·9	983
36. Masumbika	77·9	135	925	71·2	48·8	701
Other varieties of Arachis hypogaea						
37. Kurumani (var. *asiatica*)	75·0	180	787	73·4	48·9	1,268
38. var. *nambyquarae*	73·1	150	950	67·9	45·5	504
39. var. *vasterio*	78·4	180	866	71·1	48·8	527
40. var. *gigantea*	86·7	150	288	76·1	50·2	1,202

APPENDIX II—(*contd.*)

Measurable characters of typical groundnut varieties and forms

Name of variety or form	Natural test weight of one Madras measure in grams		Size of pods (cm.)			Size of kernels	
			Length		Thickness	Length	Thickness
	Pods	Kernels	From	To			
(1)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Forms under Arachis hypogaea *var.* oleifera							
1. Form erecta	686	1,301	1·5	0·4	0·5	1·6	0·6
2. Gudiyatham Bunch	652	1,325	2·9	1·3	1·0	1·3	0·8
3. Small Japan	644	1,352	3·2	1·3	1·0	1·3	0·8
4. Volete	646	1,320	2·5	1·3	1·0	1·3	0·8
5. Kumavu	549	1,342	4·8	1·3	1·6	1·4	0·8
6. Macspan	643	1,320	2·9	1·3	1·6	1·3	0·8
7. Java 1	613	1,327	3·5	1·3	1·6	1·6	1·0
8. Java 2	592	1,325	4·1	1·6	1·6	1·6	1·0
9. Valencia Peanut	543	1,327	4·5	1·6	1·6	1·4	0·8
10. Spanish Bunch (Salisbury)	519	1,323	4·5	1·6	1·6	1·6	1·0
11. Tennessee White	569	1,325	5·1	1·3	1·6	1·6	1·0
12. Corientes 1	561	1,317	4·5	1·3	1·3	1·4	0·8
13. Corientes 3	518	1,306	4·5	1·3	1·6	1·6	1·0
14. Cordoba 2	563	1,313	4·5	1·3	1·6	1·4	0·8
15. Casilda 5	653	1,323	2·5	1·0	1·3	1·3	0·8
16. Akola 24	589	1,309	3·8	1·6	1·9	1·6	1·0
17. Porte Alegre	558	1,316	2·9	1·3	1·3	1·3	1·0
18. Akola 10	432	1,107	4·5	1·8	1·5	2·0	1·2
19. H. G. 1	553	1,198	4·5	1·6	1·3	1·6	1·0
20. Spanish Bombay	597	1,226	3·2	1·6	1·3	1·6	1·0
21. Native Tanganyika	543	1,161	4·5	1·6	1·6	1·8	1·0
22. Virginia Bunch (Salisbury)	435	1,131	5·4	1·9	1·6	2·1	1·3
23. Virginia White Bunch	564	1,178	4·5	1·6	1·6	1·9	1·0
24. Gumitam Budda	676	1,226	2·8	1·6	1·0	1·4	0·8
25. Local Mauritius	645	1,214	2·9	1·3	1·0	1·6	0·8
26. Texas	475	1,142	5·4	1·8	1·6	2·2	1·1
27. Carolina	575	1,218	4·3	1·1	1·3	1·6	1·0
28. Big Japan	584	1,201	4·5	1·6	1·3	1·8	1·0
29. Mauritius Pistache	598	1,235	4·1	1·6	1·3	1·6	1·0
30. Virginia Mauritius	649	1,220	4·0	1·4	1·3	1·1	1·0
31. Saloum	576	1,204	4·0	1·6	1·3	1·6	1·0
32. Louga	666	1,225	2·4	1·1	1·0	1·3	0·8
33. Bassi	627	1,215	3·2	1·3	1·3	1·3	0·8
34. Wild Falcon A	652	1,241	3·2	1·3	1·1	1·3	0·8
35. Philippine White	576	1,238	4·1	1·4	1·3	2·1	1·0
36. Masumbika	491	1,107	5·1	1·9	1·6	2·1	1·0
Other varieties of Arachis hypogaea							
37. Kurumani (var. *asiatica*)	573	1,182	3·8	1·3	1·0	1·6	1·3
38. var. *nambyquarae*	484	1,245	5·7	1·9	1·8	2·5	1·0
39. var. *rasterio*	551	1,307	3·6	2·4	1·5	1·8	1·0
40. var. *gigantea*	600	1,169	3·0	1·5	1·0	1·4	0·8

APPENDIX II—(*contd.*)

Measurable characters of typical groundnut varieties and forms

Name of variety or form	Height of main axis	Average length of first four primaries	Average number of primaries	Average number of secondaries	Number of tertiaries	Total number of leaves
	Number of nodes	Number of nodes		Number of nodes	Number of nodes	
(1)	(15)	(16)	(17)	(18)	(19)	(20)
Forms under Arachis hypogaea *var.* oleifera						
1. Form erecta	23·3/24	22·4/16	7	9/31	—	207
2. Gudiyatham Bunch	21·2/24	17·4/14	4	—	—	95
3. Small Japan	27·6/25	19·4/16	4	—	—	102
4. Volete	18·1/25	15·9/16	5	—	—	109
5. Kumavu	25·5/26	18·7/16	4	—	—	105
6. Macspan	21·3/25	17·4/15	4	—	—	101
7. Java 1	25·5/25	20·8/15	4	—	—	100
8. Java 2	25·8/24	19·4/15	4	—	—	97
9. Valencia Peanut	29·6/27	23·8/16	4	—	—	107
10. Spanish Bunch (Salisbury)	33·6/27	30·3/18	5	—	—	117
11. Tennessee White	25·0/22	21·1/14	4	—	—	93
12. Corientes 1	23·5/25	23·2/16	4	—	—	109
13. Corientes 3	18·9/24	17·5/15	4	—	—	99
14. Cordoba 2	28·0/26	27·3/16	5	—	—	109
15. Casilda 5	21·2/25	16·3/14	4	—	—	94
16. Akola 24	25·3/24	24·6/17	5	—	—	112
17. Porte Alegre	42·9/26	36·0/17	5	—	—	111
18. Akola 10	20·5/25	20·9/18	5	—	—	293
19. H. G. 1	14·7/20	16·7/16	5	5/45	—	141
20. Spanish Bombay	16·0/20	19·0/17	5	2/16	—	110
21. Native Tanganyika	25·8/26	30·1/23	5	6/88	—	220
22. Virginia Bunch (Salisbury)	22·0/26	28·9/24	5	3/43	—	181
23. Virginia White Bunch	23·1/27	30·1/23	5	6/82	—	218
24. Gumitam Budda	17·5/23	23·0/18	5	4/51	—	284
25. Local Mauritius	16·3/22	25·3/21	4	6/76	—	194
26. Texas	20·5/26	38·4/25	5	7/110	—	266
27. Carolina	17·6/26	31·7/25	5	13/174	—	318
28. Big Japan	20·6/26	32·3/23		7/100	—	242
29. Mauritius Pistache	26·8/27	40·8/24	4	6/84	—	216
30. Virginia Mauritius	23·2/25	34·0/24	5	9/137	—	274
31. Saloum	16·7/25	27·1/23	5	7/105	—	235
32. Louga	18·0/26	30·3/24	6	8/107	—	250
33. Bassi	20·1/28	36·1/25	6	16/122	—	296
34. Wild Falcon A	17·6/29	30·6/26	6	10/154	—	313
35. Philippine White	21·6/28	34·0/27	6	13/178	—	346
36. Masumbika	36·5/28	54·2/23	5	5/70	—	206
Other varieties of Arachis hypogaea						
37. Kurumani (var. *asiatica*)	30·8/29	52·2/29	13	34/513	25/247	1,021
38. var. *nambyguarae*	23·5/25	32·9/21	6	6/81	—	215
39. var. *rusteria*	19·2/22	54·3/23	5	22/305	—	621
40. var. *gigantea*	30·2/31	106·2/33	4	1/26	—	323

APPENDIX II—(*contd.*)

Measurable characters of typical groundnut varieties and forms

Name of variety or form	Length (in cm.) of petiole stipule rachis					
	Main axis	Primary branches	Main axis	Primary branches	Main axis	Primary branches
(1)	(21)	(22)	(23)	(24)	(25)	(26)
Forms under Arachis hypogaea *var.* oleifera						
1. Form erecta	4·0	3·7	3·0	2·8	0·7	0·8
2. Gudiyatham Bunch	5·2	4·2	4·2	3·6	1·1	0·9
3. Small Japan	5·7	4·2	4·6	3·3	1·1	0·9
4. Volete	5·3	4·7	4·4	3·9	1·1	1·1
5. Kumavu	5·8	4·7	4·3	3·6	1·1	1·0
6. Macspan	5·7	4·4	4·3	3·7	1·1	0·9
7. Java 1	5·8	4·4	4·5	3·7	1·1	0·9
8. Java 2	5·7	4·5	4·4	3·6	1·1	1·0
9. Valencia Peanut	5·9	5·0	4·2	3·8	1·1	1·0
10. Spanish Bunch (Salisbury)	6·1	5·2	4·5	4·0	1·2	1·0
11. Tennessee White	5·8	4·7	4·2	3·7	1·2	1·2
12. Corientes 1	5·8	4·3	4·7	3·7	1·2	0·9
13. Corientes 3	6·3	4·9	4·4	3·5	1·3	1·1
14. Cordoba 2	6·2	5·5	4·6	4·2	1·3	1·2
15. Casilda 5	5·2	3·7	4·3	3·1	1·1	0·9
16. Akola 24	5·5	4·4	4·1	3·4	1·1	1·1
17. Porte Alegre	6·9	5·4	5·3	4·3	1·2	1·3
18. Akola 10	5·6	4·5	4·7	4·4	1·3	0·9
19. H. G. 1	4·8	3·4	3·8	3·0	0·8	0·7
20. Spanish Bombay	4·9	3·5	4·0	3·3	0·8	0·7
21. Native Tanganyika	5·2	3·7	4·0	3·3	0·9	0·8
22. Virginia Bunch (Salisbury)	5·0	4·1	4·6	3·5	1·1	0·9
23. Virginia White Bunch	5·4	4·2	4·1	3·5	1·0	0·9
24. Gumitam Budda	5·5	3·8	3·7	3·2	1·2	0·9
25. Local Mauritius	4·4	3·3	3·8	3·0	0·8	0·7
26. Texas	5·5	3·9	4·2	3·4	1·0	0·9
27. Carolina	4·7	3·3	4·6	3·2	0·9	0·6
28. Big Japan	5·1	3·5	4·0	3·2	0·9	0·7
29. Mauritius Pistache	5·6	3·9	4·3	3·4	1·0	0·8
30. Virginia Mauritius	4·8	3·6	4·0	3·1	1·0	0·8
31. Saloum	4·9	3·4	3·9	3·1	0·8	0·7
32. Louga	4·6	3·3	3·5	2·9	0·9	0·6
33. Bassi	4·7	3·7	3·8	3·3	0·9	0·8
34. Wild Falcon A	4·8	3·2	4·0	3·0	0·9	0·6
35. Philippine White	4·7	3·4	4·1	3·2	0·9	0·7
36. Masumbika	6·5	4·6	5·3	4·0	1·3	1·0
Other varieties of Arachis hypogaea						
37. Kurumani (*var.* asiatica)	4·7	3·3	3·6	2·8	0·9	0·8
38. var. *nambyquarae*	6·1	4·2	5·9	4·5	1·0	0·9
39. var. *rasterio*	5·2	4·1	4·8	3·8	1·3	1·2
40. var. *gigantea*	5·5	4·3	5·1	3·9	1·4	1·3

APPENDIX II—(*contd.*)

Measurable characters of typical groundnut varieties and forms

Name of variety or form	Size of leaflets (cm.)				Length of calyx tube (Range in cm.)	Size of standard (cm.)	Depth of pod germination (cm.)
	Main axis		First pair of primaries				
	1st Pair	2nd pair	1st pair	2nd pair			
(1)	(27)	(28)	(29)	(30)	(31)	(32)	(33)
Forms under Arachis hypogaea *var.* oleifera							
1. Form erecta	3·5×2·0	3·2×1·8	3·0×1·5	2·7×1·4	3·0—3·5	1·4×1·2	—
2. Gudiyatham Bunch	4·5×2·0	4·1×1·8	4·0×1·9	3·6×1·7	3·0—4·5	1·6×1·3	2·0
3. Small Japan	5·0×2·2	4·4×2·0	4·6×2·4	4·1×2·1	2·4—4·5	1·7×1·4	1·7
4. Volete	3·7×1·8	3·2×1·6	3·9×1·8	3·1×1·5	2·5—4·5	1·7×1·3	2·2
5. Kumavu	4·4×1·9	3·5×1·5	3·7×1·7	3·2×1·5	2·5—4·5	1·6×1·3	2·0
6. Macspan	4·2×2·0	3·8×1·6	3·9×1·9	3·6×1·8	2·8—4·5	1·6×1·3	2·0
7. Java 1	4·8×2·3	4·2×2·0	5·0×2·4	4·3×2·0	3·0—5·5	1·7×1·4	2·1
8. Java 2	5·4×2·4	4·8×2·1	4·5×2·2	4·2×2·0	3·0—5·0	1·7×1·	2·3
9. Valencia Peanut	4·5×2·0	3·8×1·6	3·7×1·7	3·2×1·5	3·0—5·0	1·7×1·4	2·0
10. Spanish Bunch (Salisbury)	4·6×2·2	4·1×1·7	3·7×1·7	3·2×1·5	3·0—4·5	1·6×1·3	2·0
11. Tennessee White	5·1×2·3	4·4×2·0	4·4×2·2	3·9×1·9	3·0—5·0	1·7×1·3	1·9
12. Corientes 1	4·7×1·9	4·1×1·7	3·9×1·8	3·5×1·6	3·0—5·0	1·6×1·4	2·5
13. Corientes 3	5·0×1·7	4·3×1·7	4·2×1·9	3·7×1·6	2·5—5·0	1·6×1·3	2·4
14. Cordoba 2	4·5×1·9	4·4×1·7	4·2×1·9	3·9×1·7	3·0—5·0	3·6×1·3	1·7
15. Casilda 5	4·7×2·2	4·2×1·9	3·7×1·8	4·0×1·9	3·0—5·5	1·7×1·3	1·7
16. Akola 24	4·8×2·3	4·4×2·0	4·4×2·5	4·1×2·1	3·0—4·5	1·6×1·3	2·3
17. Porte Alegre	5·3×2·2	4·5×1·9	4·6×2·0	3·9×1·7	3·0—4·5	1·6×1·3	2·2
18. Akila 10	4·3×1·9	4·0×1·6	3·8×1·9	3·3×1·7	3·0—3·5	1·7×1·5	8·0
19. H. G. 1	3·2×1·4	2·7×1·2	3·0×1·6	3·6×1·3	2·9—3·5	1·7×1·5	2·8
20. Spanish Bombay	3·5×1·7	3·2×1·5	3·5×1·7	2·8×1·4	2·5—4·5	1·7×1·4	2·6
21. Native Tanganyika	4·6×2·0	4·1×1·7	3·9×1·8	3·3×1·5	2·5—4·5	1·7×1·4	2·6
22. Virginia Bunch (Salisbury)	4·1×1·8	3·7×1·5	3·6×1·7	3·4×1·5	2·0—4·5	1·8×1·5	2·6
23. Virginia White Bunch	4·2×1·9	3·8×1·6	3·7×1·8	3·4×1·5	2·0—3·5	1·7×1·5	2·9
24. Gumitam Budda	4·3×1·9	4·0×1·6	3·8×1·9	3·3×1·7	2·3—2·8	1·4×1·3	3·0
25. Local Mauritius	3·7×1·6	3·3×1·4	3·1×1·6	2·7×1·4	2·0—3·5	1·5×1·3	2·6
26. Texas	4·6×1·8	4·0×1·6	4·0×1·9	3·5×1·7	3·0—4·0	1·6×1·5	2·7
27. Carolina	4·0×1·7	3·6×1·5	3·5×1·7	3·1×1·5	2·5—4·0	1·7×1·5	3·0
28. Big Japan	3·8×1·8	3·4×1·5	3·4×1·7	3·0×1·5	2·5—4·0	1·8×1·5	2·9
29. Mauritius Pistache	4·2×1·7	3·7×1·5	3·9×1·9	3·4×1·7	2·5—3·5	1·7×1·4	3·7
30. Virginia Mauritius	4·2×1·8	3·6×1·5	3·9×2·0	3·3×1·7	2·5—4·0	1·7×1·4	2·9
31. Saloum	3·7×1·7	3·5×1·5	3·5×1·8	3·1×1·5	2·5—3·5	1·6×1·4	2·7
32. Louga	3·3×1·7	2·9×1·4	2·7×1·5	3·0×1·7	2·0—3·0	1·6×1·4	2·0
33. Bassi	3·5×1·8	3·0×1·4	3·0×1·7	2·6×1·5	2·0—3·0	1·4×1·6	2·2
34. Wild Falcon A	3·8×1·7	3·4×1·4	3·3×1·6	2·8×1·4	2·0—3·5	1·6×1·4	3·3
35. Philippine White	4·0×1·7	3·7×1·6	3·5×1·7	3·0×1·4	2·0—3·0	1·6×1·4	2·2
36. Masumbika	5·5×2·5	4·8×2·0	4·5×2·3	4·1×2·1	2·5—4·5	1·9×1·7	3·4
Other varieties of Arachis hypogae							
37. Kurumani (var. *asiatica*)	4·1×1·9	3·4×1·5	3·1×1·5	2·6×1·2	2·0—3·0	1·6×1·4	4·0
38. var. *nambyqyarae*	6·1×2·0	5·3×1·6	5·0×1·9	4·4×1·6	2·5—3·5	1·9×1·6	3·5
39. var. *rasterio*	5·3×2·2	4·5×1·8	4·2×2·3	3·6×1·9	3·0—5·5	1·9×1·6	2·7
40. var. *gigantea*	5·2×2·2	4·9×1·9	4·5×2·4	3·8×1·9	3·0—6·0	1·6×1·5	3·6

APPENDIX III

Classification of groundnut varieties and forms

Characters of classificatory value				Type	Other synonymous forms	Similar type described by previous workers
Habit of growth	Tests colour	Kerneled nature of pods	Size of pods			
		FORMS UNDER *Arachis hypogaea* VAR. *oleifera*				
Erect	Rose	1—3	Tiny	Forma erecta		
Bunch	Light rose	1—2	Very small	Volete	Spanish 10, Mac Span, Casilda 5, Florida II, III and IV.	'Manchurian' type of Luzina
,,	,,	1—2	Small	Gudiyatham Bunch	Valencia White, San Jose (Philippine), Reconquista 6.	'Spanish' type of Luzina
,,	,,	1—3 (3 occasional)	Medium	Java 2	North Carolina Peanut, Java 1, 3, 4, 5, Spanish (Philippine).	'Java' type of Luzina
,,	,,	1—4	Small	Corientes-1		
,,	,,	1—4	Medium	Tennessee White	Cordoba 2	
,,	Rose	1—3	Big	Akola 10		
,,	Red	1—2	Small	Small Japan		
,,	,,	1—4	Medium	Kumavu	Valencia Peanut, Bunch Mozambique, Spanish Bunch (Salisbury), Virginia Bunch (Tanganyika), Tennessee Red, Cordoba 4, Monteco Seros 7 and 8.	'Valencia' type of Luzina
,,	Dark purple	1—4	Medium	Corientes-3		
,,	,,	1—4	Big	Porte Alegre		
Semi-spreading	Rose	1—2	Small	Gumitam Budda		
,,	,,	1—2	Medium	Spanish (Bombay)		
,,	,,	1—3	Medium	Native Tanganyika	Virginia White Bunch	This approaches Luzinas 'African' type
,,	,,	1—3	Big	Virginia Bunch (Salisbury)		
Spreading	White	1—3	Medium	Philippine White		
,,	Rose	1—2	Very small	Louga	Baol	

APPENDIX III—(*contd.*)

Classification of groundnut varieties and forms

Characters of classificatory value				Type	Other synonymous forms	Similar type described by previous workers
Habit of growth	Tests colour	Kerneled nature of pods	Size of pods			
Spreading	Rose	1—3 (3 occasional)	Very small	Wild Falcon A	Wild Falcon B.	
,,	,,	1—2	Small	Local Mauritius	Sogathur, Mozambique Mauritius, Gooty.	
,,	,,	1—3 (3 occasional)	Small	Bassi	Zaria, Gambia, Philippine Pink.	
,,	,,	1—3	Medium	Big Japan	Kalahasti, Virginia Runner, Carolina, Chiba 63, Chiba 73, Transvall, West African, Madagascar, Barbados Ceylon, Rufisque Senegal, Senegal, Local Pondicherry.	
,,	,,	1—3 (3 Occasional)	Big	Texas	Rangoon, Virginia Running Peanut, Mauritius Virgini, Jumbo Runner	Identical with the Virginia type of Luzina. Nearly answers the description of the Peru type of Luzina.
,,	,,	1—3	Big	Musumbika		
				OTHER VARIETIES OF *Arachis Hypogaea*		
Semi-spreading	Rose	1—4	Small	Kurumani	Var. *asiatica*	Identical with the 'Khasgar' type of Luzina.
,,	Red (Testa ruptured)	1—2	Very big	var. *nambyquarae*		
Spreading	Red	1—2	Big	var. *rasteiro*		
Trailing	Rose	1—2	Small	var. *gigantea*		

APPENDIX IV

Key for the identification of groundnut varieties and forms

A. Seed coat splitting—

B. Habit semi-spreading ; branches short ; leaflets elliptic, long, narrow, pale-green ; pods very big ; beak and veins very prominent ; constriction medium to shallow ; seeds big, elongated and flattered, not plump ; testa red, ruptured ; duration 150 days. — *var. nambyvuarae*

BB. Habit spreading ; branches long ; leaflets medium sized, obovate, dark green ; pods big ; beak distinct ; veins prominent ; constriction shallow ; seeds big ; rounded, plum, testa red, ruptured ; duration 180 days. — *var. rasteiro*

AA. Seed coat not-splitting—

C. Habit erect ; pods tiny, 1-3 seeded ; beak not distinct ; veins not distinct ; constriction shallow . . . — *forma erecta*

CC. Habit bunch. D. Testa dark purple ; pods 1-4 seeded. E. Medium sized ; beak prominent ; veins not distinct ; growth stunted. — *Corientes 3*

EE. Big ; beak not distinct, veins not distinct (smooth) ; Plant robust . . . . . — *Porte Alegre*

DD. Testa not dark purple. F. Testa red, G. Pods small, 1-2 seeded ; beak distinct ; veins distinct . — *Small Japan*

GG. Pods medium, 1-4 seeded. H. Main axis normal—

I. Veins distinct ; constriction shallow to medium . . . . . — *Valencia Peanut*

II. Veins not distinct ; constriction shallow (beaded appearance) . . . . . — *Kumavu* (Tennessee Red = Cordoba 4 and Monteco Seros 7 and 8)

HH. Main axis long ; veins not distinct ; constriction shallow (beaded appearance) . . . . . — *Spanish Bunch* (Salisbury)

FF. Testa not red. J. Testa rose ; pods big, 1-3 seeded, beak prominent, veins not distinct . . . . — *Akola 10*

JJ. Testa light rose. K. Pods very small, 1-2 seeded ; beak not distinct ; veins distinct ; L. Stunted growth — *Volete* (= Florida II)

LL. Normal growth. M. Constriction medium to deep . . . . . — *Macspan* (= Spanish 10 Florida I & III and Reconquista 6)

MM. Constriction shallow to medium . . . . . — *Casilda 5*

KK. Pods small—N. one to two seeded ; beak distinct ; veins distinct . . . . . — *Gudiyatham Bunch* (= Valencia White and San Jose Philippine)

NN. 1-4 seeded ; beak prominent ; veins distinct . . . . . — *Corientes 1*

KKK. Pods medium O. 1-3 seeded, 3 seeded occasional. P. Beak distinct ; veins distinct—

Q. Leaflets large . . . . . — *Java 1* (=Java 3 & Spanish Philippine).

QQ. Leaflets very large . . . . . — *Java 2* (=Java 4 and Java 5)

PP. Beak and veins not so distinct . . . . . — *Akola 24* (=North Carolina Peanut, Improved Spanish and Improved Spanish 2-B)

APPENDIX IV—(*contd.*)

Key for the identification of groundnut varieties and forms

00. 1—4 seeded—R. Beak distinct, veins distinct . . . . . *Tennessee White*

RR. Beak distinct ; veins not distinct . . . . . *Corodoba 2*

CCC. Habit semi-spreading—

S. Pods 1—2 seeded. T. Small ; beak prominent ; veins distinct . . . . . *Gumitam Budda*

TT. Medium ; beak distinct ; veins distinct ; medium duration . . . . . *Spanish Bombay*

SS. Pods 1—3 seeded, 3 seeded occasional ; beak distinct ; veins not distinct . . . . *Virginia White Bunch*

SSS. Pods 1—3 seeded U. Medium ; beak prominent ; veins not distinct—

V. Plant robust, duration 130 days . . . . . *Native Tanganyika*

VV. Plant stunted duration 120 days . . . . . *H. G. 1*

UU. Big ; beak distinct ; veins distinct . . . . . *Virginia Bunch* (Salisbury)

SSSS. Pods 1—4 seeded, small ; beak and veins very prominent ; constriction shallow (beaded appearance) ; highly pubescent. *Kurumani* (var. *asiatica*)

CCCC. Habit spreading W. Testa white ; pods 1-3 seeded, medium ; beak prominent ; veins not distinct ; devoid of pigment. *Philippine white*

WW. Testa not white, rose. Pods very small Y. 1—2 seeded, beak and veins not distinct . . *Louga* (Baol)

YY. 1—3 seeded, 3 seeded rare ; beak and veins distinct ; beak-end recurved . . . . . *Wild Falcon A* (=Wild Falcon B)

XX. Pods small. Z. 1—2 seeded ; beak prominent ; veins distinct . . . . . *Local Mauritius* (Sogathur, Mozambique Mauritius & Gooty)

ZZ. 1—3 seeded, 3 seeded occastion ; beak not (distinct) ; rounded ; veins distinct ; constriction shallow. *Bassi* (=Zaria, Gambia, Philippine Pink)

XXX. Pods medium—

a. 1—3 seeded, 3 seeded occasional—

b. Beak prominent ; veins prominent . . . . . *Mauritius Pistache*

bb. Beak Prominent ; veins not distinct . . . . . *Saloum* (=Virginia Bunch)

bbb. Beak distinct ; veins distinct . . . . . *Virginia Mauritius*

aa. 1—3 seeded—

c. Beak prominent ; veinr not distinct . . . . . *Carolina* (=Kalahasti, Tata, Chiba 63, Chiba 73, Madagascar, Rufisque Senegal, Senegal, Local Pondy)

cc. Beak not so prominent ; veins not distinct . . . . . *Big Japan* (=Barbados Ceylon, West African and Virginia Runner)

XXXX. Pods big—

d. 1—3 seeded, 3 seeded occasional ; beak prominent ; veins not distinct . . . . . *Taxas* (=Rangoon Virginia Running Peanut, Mauritius Virgini and Jumbo Runner)

dd. 1—3 seeded ; beak prominent ; veins distinct ; plant robust . . . . . *Masumbika*

CCCCC. Habit trailing ; testa rose, pods small, 1—2 seeded ; beak prominent ; veins not distinct ; plant robust . var. *Gigantea*

APPENDIX V

Note on groundnut strains under distribution in Madras State

T. M. V. 1 (A. H. 25). A mass selection isolated from the West African form 'Saloum'. Plants vigorous with spreading habit of growth. Gives more than 25 per cent increased yield over the local (Local Mauritius). The strain is also drought resistant. *Leaflets* : small, dark green. *Pods* : medium sized, 1-3 seeded, 3 seeded very occasional. *Beak* : prominent ; *Veins* : not distinct ; *Constriction* : shallow ; *Shell* : medium thickness. *Kernels* : medium, rose, oblong, somewhat plump, dormant. Duration 135 days.

Average acre yield of pods	1,450 lb.
Proportion of kernels to pods	73·5 per cent
Weight of one Madras measure of pods	1 lb. 4 oz.
Weight of one Madras measure of kernels	2 lb. 11½ oz.
Number of kernels per pound	950
Oil content of kernels	49·0 per cent

T.M.V. (A.H.32). A mass selection from the 'Spanish' type grown extensively in North Arcot, Guntur and other districts of Madras State. A short duration (105 days) type with bunch habit of growth. Cannot stand long periods of drought. *Leaflets* : large, light green. *Pods* : small, 1 to 2 seeded. *Beak* : distinct ; *Veins* : distinct ; *Constriction* : shallow to medium ; *Shell* : very thin. *Kernels* : very small, light rose, rounded, plump, non-dormant.

Average acre yield of pods	1,625 lb.
Proportion of kernels to pods	76·7 per cent
Weight of one Madras measure of pods	1 lb. 5½ oz.
Weight of one Madras measure of kernels	2 lb. 13¾ oz.
Number of kernels per pound	1,470
Oil content of kernels	49·4 per cent

T.M.V. 3 (A.H. 698). A pure line isolated from the West African form '*Bassi*'. *Plants* : vigorous with spreading habit of growth. Gives more than 30 per cent increased yield over the local (Local Mauritius). *Leaflets* : small, dark green. *Pods* : Small, 1 to 3 seeded very occasional. *Beak* : not distinct (rounded) ; *Veins* : distinct ; *Constriction* : shallow ; *Shell* : thin. *Kernels* : small, rose, rounded, not plump, dormant. Duration 135 days.

Average acre yield of pods	1,450 lb.
Proportion of kernels to pods	76·8 per cent
Weight of one Madras measure of pods	1 lb. 6½ oz.
Weight of one Madras measure of kernels	2 lb. 12 oz.
Number of kernels per pound	1,150

T.M.V. 4 (A.H. 334). A pure line isolated from the American form '*Carolina*. *Plants* : vigorous with spreading habit of growth. Gives an average increased yield of 30 per cent over the local (Local Mauritius) ; *Leaflets* : Small, dark green. *Pods* : medium sized, 1—3 seeded, 3 seeded many. *Beak* : prominent ; *Veins* : not distinct ; *Constriction* : shallow to medium ; *Shell* : thin. *Kernels* : medium to small, rose elliptic, not plump, dormant. Duration 135 days. Comes up well even under irrigation and hence recommended for irrigated cropping during summer (February-July).

Average acre yield of pods	1,425 lb.
Proportion of kernels to pods	75·5 per cent
Weight of one Madras measure of pods	1 lb. 4½ oz.
Weight of one Madras measure of kernels	2 lb. 11½ oz.
Number of kernels per pound	940
Oil content of kernels	50·4 per cent

MANURING OF WHEAT

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ONE of the successful methods of increasing crop production is by providing adequate amounts of nutrients for plant growth. Where irrigation facilities exist, it has been established that the easiest and quickest way of increasing production is through manuring.

The soils in India are deficient in organic matter and nitrogen in general and phosphorus in localized areas. The soils at the Indian Agricultural Research Institute are mostly deficient in nitrogen and organic matter.

Wheat is an important food crop in India and over 25 per cent of the area has assured irrigation facilities.

* Experiments on manuring of wheat have been in progress since 1948 on various aspects and the summary of the results obtained during the period 1948-52 is given in this paper.

Nitrogen has been found to be the dominant requirement of wheat and as such great stress has been laid on the application of nitrogen. Nitrogen can be obtained through farm yard manure, green manure, cakes or fertilizers. The experiments were therefore conducted on all the above-mentioned forms supplying nitrogen.

The different experiments have been conducted at different places. The texture of soil varied between loam and sandy loam. The soils were generally rich in K_2O. As regards other items these varied within the following ranges :

**Item	Range
1. *p*H	8·100—7·300
2. Nitrogen	0·069—0·039
3. Total P_2O_5	0·170—0·057
4. Available P_2O_5 (per cent)	0·019—0·015
5. CaO (per cent)	2·600—1·000
6. Organic matter (per cent) (Loss on ignition)	4·000—2·600

* These experiments were initiated and started by the author. Some of these experiments were taken up by the Post-graduate students for their research problems. In addition to this Shri L. L. Relwani assisted during 1949-50 and Shri S. R. Obhrai from 1948-51 in some of the problems. The different experiments which have since been completed are being written up in association with different workers. This paper deals only with a summary of the main results.

**The soil samples were sent to the Head of the Division of Chemistry and got analysed in his laboratories.

During the period 1948-52, the following aspects have been studied :

1. Effect of farm yard manure . . Its doses and economics.
2. Effect of green manuring . . Its effect, form and economics.
3. Effect of cakes . . . . Doses and economics.
4. Nitrogenous fertilizers . . Form, doses, time of application and economics.
5. Varietal response to nitrogenous fertilizers.
6. Sowing date response to nitrogenous fertilizers.
7. Fertilization of wheat in different rotations.
8. Effect of nitrogen, P_2O_5, K_2O—singly or in combination.

Effect of farm yard manure

The experiments on the value of farm yard manure as manure have been conducted both on the basis of nitrogen and tonnage. The manure was applied 6-7 weeks before sowing. The results of last three years are summarised in Table I.

Table I

**The effect of farm yard manure when applied at different levels of nitrogen*

Treatment	Yield of wheat in maunds/acre (Average of 1948-49 to 1951-52)	Per cent increase over control	Response in pounds per lb. nitrogen	Profit (+) Loss (—) in rupees per acre
A. Control	24·60	..	..	..
B. 40 16. N/acre	24·80	0·10	0·40	—15·60
C. 60 do.	26·40	7·30	2·20	+2·85
D. 80 do.	26·40	7·30	1·60	—5·90
E. 100 do.	28·10	14·20	2·90	+14·25
F. 120 do.	27·00	9·70	1·60	—13·20

Table II

**The effect of farm yard manure when applied on the basis of tonnage*

Treatment (Dose of F. Y. M.)	Yield of wheat grain in maunds (Average of 1948-49 to 1951-52)	Per cent increase over control	Response in maunds per ton of F.Y.M.	Profit (+) Loss (—) in rupees per acre
A. Control	19·50	..	..	..
B. 5 tons per acre	20·30	4·00	0·16	—22·90
C. 10 do.	23·70	21·00	0·42	+0·10
D. 15 do.	27·00	38·00	0·50	+21·00
E. 20 do.	29·10	49·00	0·48	+21·70
F. 25 do.	30·80	58·00	0·46	+15·60

* F.Y.M. at Rs. 7 per ton.
F.Y.M. contained 0·8 per cent total nitrogen.

It will be seen from Tables I and II that farm yard manure when added on nitrogen basis has shown very negligible response. Even with 100 lb. of ni rogen as farm yard manure only 14 per cent increase has been obtained with a response of 2·9 lb. of grain per pound of nitrogen.

When farm yard manure is added on the basis of tonnage, it is observed that up to five tons, there is hardly any increase. Appreciable increases can be obtained with the application of ten tons or more per acre. It has been possible to get 20 per cent increase with 10 tons and 60 per cent increase with 25 tons of farm yard manure per acre respectively. With ten tons and above a response of 0·4 to 0·5 maund of grain per ton of farm yard manure has been obtained.

The results indicate that increased yields of wheat can only be possible with farm yard manure when applied in large quantities. In small quantities it appears that farm yard manure has very little manurial value. The experiments are still in progress.

Effect of green manuring

Choice of crop for green manuring in kharif

The work is in progress since 1950. Several *kharif* legumes are grown with and without 80 lb. P_2O_5 per acre. These are buried at the age of 7—8 weeks and crop of wheat N.P. 718 is taken to study the relative value of different *kharif* legumes for green manuring. The results of year 1950 are given in Table III.

Table III

The quantity of green matter buried and yield of wheat in maunds per acre

Treatment	Quantity of green matter buried in md./acre	Average yield of wheat in md./acre	Per cent increase over control
A. *Guar* (*Cyamopsis psoraliodes*)	162·9	24·6	35·7
B. Sannhemp (*Crotolaria juncea*)	189·0	24·5	35·4
C. Cowpeas (*Vigna sinensis*)	169·7	22·2	22·6
D. Soyabean (*Glycine hispida*)	170·6	23·0	27·2
E. *Dhaincha* (*Sesbania aculeata*)	155·3	23·1	27·4
F. Control	..	18·1	..

All the green manuring crops have helped to give significantly higher yields of wheat than the control. The increase varies between 22 to 35 per cent. Under the local conditions, crops of *guar* (*Cyamopsis psoraloides*) and sannhemp (*Crotolaria juncea*) are the best followed by *dhaincha* (*Sesbania aculeata*). The experiment is still in progress.

Value of green manuring and its economics

This experiment was laid down in 1950-51 and is in progress. The results of two years which are now available are given in Table III(*a*).

TABLE III(*a*)

Yield and profit accrued from crops under different treatments

	Treatment		Average yield of wheat (N.P.4) or peas N.P. 29 in md./acre	Average net profit from crops of both seasons in rupees/acre	
	Kharif	*Rabi*		Rs.	A.
A.	Maize	Fallow	..	100	10
B.	Fallow	Wheat	15·0	231	8
C.	Maize	Wheat	8·8	231	0
D.	Maize +10 tons of F.Y.M./acre	Wheat	11·2	185	10
E.	Maize	Peas	7·5 (Peas)	184	8
F.	Sannhemp green-manure +60 lb. P_2O_5/acre	Wheat	17·8	236	6
G.	Groundnut +60 lb. P_2O_5/acre	Wheat	12·9	126	6
H.	Sannhemp grown in alternate rows with maize and buried +60 lb. P_2O_5 per acre	Wheat	13·8	224	3

The value of green manuring is clearly marked out. An increase of 19 per cent has been obtained over fallow, 29 per cent over green manuring in alternate rows with maize, 38 per cent over legumes in rotation and 100 per cent over cereal rotation.

As regards economics, this is a long term experiment. As the years pass the yields will progressively go on decreasing in cereal rotation while they will go on increasing in rotations having fallow, legumes and green manuring. The practice of green manuring has thus both immediate and cumulative benefit. Even in the very first two years of experiments the treatment of green manuring has given the maximum profit per acre in spite of the fact that only one crop of wheat was taken.

It is thus seen that the practice of green manuring can give an increased production between 20 to 40 per cent depending on soil conditions and that it is economical.

The experiment is in progress and would continue for a long period.

EFFECT OF CAKES

Groundnut cake, which is easily available, has been used as manure to see the effect on wheat C.518. The nitrogen content varied between 6·0 and 7·0 per cent.

The cake was powdered in grinding mill and applied six to seven weeks before sowing. The experiment is under progress since 1949. The results of last three years are summarised in Table IV.

TABLE IV

Effect of cake on the yield of wheat

Treatment	Average yield of wheat grain in md./acre (1949-50 to 1951-52)	Per cent increase over control	Response in pounds per lb. of nitrogen	Profit (+) Loss (—) in rupees per acre
A. Control	24·6	..	..	..
B. 40 lb. nitrogen per acre as groundnut cake	29·6	20·5	10·3	+23·5
C. 60 lb. N. per acre as groundnut cake	30·5	23·8	8·0	+8·8
D. 80 lb. nitrogen per acre as groundnut cake	33·0	34·1	8·6	+21·3

It will be seen from the figures under Table IV that the application at higher doses results in higher yields per acre but is comparatively more costly and less responsive. The application of 40 lb. nitrogen appears to be the optimum dose for wheat. The effect of lower dose than 40 lb. nitrogen is also under study. The experiment is in progress.

NITROGENOUS FERTILIZERS

Form of nitrogenous fertilizers

The nitrogenous fertilizers are available in the forms of (i) ammonium sulphate, (ii) Chilean nitrate (sodium nitrate), (iii) ammonium nitrate, (iv) urea, (v) calcium cyanamide, (vi) ammonium chloride, (vii) calcium nitrate, (viii) nitro chalk and (ix) ammonium nitro-sulphate. It was not possible to test all these forms as they were not easily available. Only four forms which were available were tested as under :

i. Ammonium sulphate — The form commonly used in the world.

ii. Chilean nitrate — The oldest form of nitrogenous fertilizer in the world.

iii. Ammonium nitrate, iv. Urea — These are of recent introduction and are concentrated fertilizers.

It will be further seen that these four forms also give a comparison between (*a*) ammoniacal nitrogen only, (*b*) nitric nitrogen only, (*c*) ammoniacal and nitric

nitrogen combined, (*d*) amide nitrogen and (*e*) concentrated and less concentrated fertilizers.

The experiment on the above-mentioned four forms was started in the year 1949-50 and concluded in 1951-52. The soil was of sandy loam texture having a *p*H varying between 8·0—8·1. The nitrogen content varied between 0·055 to 0·046 per cent and available P_2O_5 between 0·018 to 0·0147 per cent. The fertilizers were applied as top dressing with irrigation in January every year. In the first two years N.P. 52 variety of wheat was grown and in the third year N.P. 718 was grown. The results of three years are summarised in Table V.

TABLE V

Results of three years experiment on four forms of fertilizers at different levels

Treatment	Average yield of 3 years of wheat grain in md./acre (1949-50 to 1951-52)	Per cent increase over control	Response in pounds per lb. of nitrogen	Profit (+) Loss (—) in rupees per acre
A. Control	14·9	..	..	..
B. Ammonium sulphate at 20 lb. N per acre	21·7	45·7	27·9	96·6
C. Ammonium sulphate at 40 lb. N per acre	22·7	52·4	16·0	98·6
D. Ammonium nitrate at 20 lb. N per acre	20·9	40·0	24·5	89·9
E. Ammonium nitrate at 40 lb. N per acre	21·8	46·3	14·1	109·9
F. Chilean nitrate at 20 lb. N per acre	20·6	38·2	23·6	87·7
G. Chilean nitrate at 40 lb. N per acre	21·7	45·7	13·9	82·3
H. Urea at 20 lb. N per acre	19·4	30·2	18·5	+72·9
I. Urea at 40 lb. N per acre	19·9	33·6	10·3	68·4

It will be seen from Table V that the application of nitrogen in the form of ammonium sulphate has given the highest increase followed by ammonium nitrate and Chilean nitrate which are nearly equal. The application of nitrogen in the form of urea has given the least increase. The increase of yield over the control has been obtained with all forms, and that the use of any commercial fertilizer is economical.

Effect of doses of application of nitrogenous fertilizer

There have been several experiments in progress since 1948-49 where different doses of nitrogen have been under test. Nitrogen has been applied in the form of

ammonium sulphate as top dressing with first irrigation in the month of January. The results of various experiments are summarised in Tables VI to IX.

TABLE VI

The yield and response of different doses of sulphate of ammonia on wheat C.-518

Treatment	Average yield of 3 years of wheat grain in md./acre (1949-51)	Per cent increase over control	Response in pound per lb. of nitrogen		Profit (+) Loss (—) in rupees per acre
			In presence of P_2O_5 & K_2O	In absence of P_2O_5 & K_2O	
N P K					
A. 0—0—0 (No manure)	19·0	..	..	..	..
B. 0—60—40 (Control)	20·1	..	..	..	..
C. 10—60—40	23·6	17·4	37·7	28·7	+48·0
D. 20—60—40	23·9	18·9	20·0	14·6	+43·1
E. 30—60—40	22·9	13·9	10·7	7·6	+16·1
F. 40—60—40	24·7	22·9	11·7	9·4	+36·7
G. 50—60—40	26·6	32·3	10·7	10·6	+59·0
H. 60—60—40	24·6	22·4	7·7	6·1	+15·0
I. 70—60—40	23·9	18·9	6·3	4·3	—6·9
J. 80—60—40	27·2	35·3	8·5	7·3	+39·2
K. 90—60—40	26·7	32·80	7·0	6·0	+20·7
L. 100—60—40	25·8	28·40	5·6	4·7	—4·6

It will be seen from Table VI that the application of first 10 lb. of nitrogen gives the highest response. The response gets decreased and after 20 lb. of nitrogen, the response becomes more or less steady. The increase in yield has been observed over the control in all the treatments. The highest increase in yield over the control and no manure has been obtained with the application of 80 lb. of nitrogen followed by 90 lb., 50 lb. and 100 lb.

It is also clear from column 4 that the response to the application of nitrogen is more in presence of P_2O_5 and K_2O.

The highest profit has been obtained with the application of 50 lb. of nitrogen, followed by 10, 20, 80 and 40 lb. of nitrogen.

The optimum dose appears to be 20 lb. of nitrogen per acre. The experiment is still in progress.

ii. In another experiment an application of 20 and 40 lb. of nitrogen as sulphate of ammonia gave the results as shown in Table VII.

TABLE VII

Effect of ammonium sulphate on wheat at different levels

Treatment	Average yield of wheat (C.-518) grain in md./acre (1949-52)	Per cent increase over control	Response in pounds per lb. of nitrogen	Profit (+) Loss (—) in rupees per acre
A. No manure	24·7	..	..	..
B. Sulphate of ammonia at 20 lb. N. per acre	28·1	13·8	13·9	+36·3
C. Sulphate of ammonia at 40 lb. per acre	28·3	14·6	7·9	+19·7

The results indicate that higher yields of wheat can be obtained with nitrogen fertilization. Application of 40 lb. nitrogen though gives slightly higher yield than 20 lb. of nitrogen, yet one can get better response and more net return with the application of 20 lb. of nitrogen.

iii. In still another experiment an application of 20 and 40 lb. nitrogen per acre as sulphate of ammonia gave the results as shown in Table VIII.

TABLE VIII

Results of second experiment on the effects of ammonium sulphate on wheat

Treatment	Yield in md./acre of wheat (N.P. 165, 760 & 771). Average of 3 years (1949-50 and 1951)	Per cent increase over control	Response in pounds per lb. of nitrogen	Profit (+) Loss (—) in rupees per acre
A. No manure	10·6	..	..	..
B. 20 lb. of nitrogen as sulphate of ammonia	13·0	22·7	9·7	+19·5
C. 40 lb. of nitrogen as sulphate of ammonia	14·0	32·1	6·8	+16·3

Here also an application of 40 lb. nitrogen per acre has given higher yield of grain per acre, but less response and less net return compared to the same obtained by the application of 20 lb. of nitrogen per acre.

iv. In an experiment on different forms of nitrogenous fertilizers on average effect of application of nitrogen has been worked out as shown in Table VIII (a).

TABLE VIII (a)

Average effect of application of nitrogen

Treatment	Average yield of wheat in md./acre	Per cent increase over control	Response in pounds per lb. of nitrogen
A. No manure	14·90	..	..
B. 20 lb. nitrogen per acre	20·61	37·7	23·4
C. 40 lb. nitrogen per acre	21·55	44·6	13·6

The average effect of all the experiments on the effect of different doses of nitrogen is summarised in Table IX.

TABLE IX

Average effect of all the experiments

Treatment	Average yield of wheat in md./acre	Per cent increase over control	Response in pounds per lb. of N	Profit (+) Loss (—) in rupees per acre
A. No manure (Control)	17·3	..	..	..
B. 20 lb. of nitrogen/acre	21·4	23·7	16·8	+48·20
C. 40 lb. of nitrogen/acre	22·14	28·0	9·9	+40·78

It will be seen that the application of higher dose, i.e. 40 lb. of nitrogen per acre has given higher yield than 20 lb. of nitrogen per acre. The response per lb. of nitrogen and net profit per acre are, however, greater with the application of lower dose, i.e. 20 lb. of nitrogen per acre. Application of 20 lb. of nitrogen to wheat is thus the optimum dose.

Time of application

The information about the time of application of nitrogenous fertilizer is as important as the dose or the form. The detailed study on the time of application has only been started this year. In the past, few studies were made and their results are summarised in Table X.

TABLE X

Average yield of wheat grain in maunds per acre (N.P. 165, 710 and 771)

Treatment	Years		
	1949-50	*1950-51	1951-52
1. Nitrogen applied at the time of sowing	18·4	16·8	6·1
2. Nitrogen applied with first irrigation as top dressing	20·4	13·7	6·3

* Some plots developed saline patches and growth was not uniform in all plots.

The results though are not conclusive, indicate that the correct time of application is an important fact in the use of fertilizers. It is likely that under the condition of experiments, top dressing with first irrigation would give better results. Further work is in progress.

Varietal response to nitrogen

This aspect has been studied with some varieties evolved by the Division of Botany, Indian Agricultural Research Institute, Departments of Agriculture, Punjab and Uttar Pradesh. The experiment was conducted under the following condition : The land was fallow during summer and received good tillage. This was considered to be normal condition for wheat growth. In one-half wheat crop was grown without any addition of fertilizers and in the other half fertilizers were added to produce condition of rich soil. The results of last three years obtained under the above-mentioned condition are summarised in Table XI.

Table XI

Varietal response to nitrogen

Variety	Yield of wheat grain in md./acre (Average of 3 years) 1949-52		Per cent increase over no manure	Response in pound per lb. of nitrogen
	No manure	N.P.K. 20-30-20		
1. N. P. 12	17·6	21·0	19·3	14·0
2. N. P. 165	23·8	26·3	10·5	10·3
3. N. P. 710	21·9	21·2	—3·2	—2·9
4. N. P. 715	19·7	21·1	7·1	5·8
5. N. P. 718	23·4	24·8	16·0	5·8
6. N. P. 721	21·6	22·2	2·3	2·5
7. N. P. 760	19·4	21·7	11·8	9·5
8. N. P. 775	23·9	21·4	—10·4	—10·3
9. C-13 (U. P. 20)	21·4	22·6	5·6	4·9
10. C-228 (Pb.)	20·1	22·3	10·9	9·0
11. C-518 (Pb.)	22·8	25·6	12·3	11·5
12. C-591 (Pb.)	23·9	23·5	—1·7	—1·6
	Average of 2 years (1950-51 and 51-52)			
1. N.P. 4	13·2	17·1	29·5	15·9
2. N. P. 80-5	13·8	15·7	14·8	10·1
3. C-217 (Pb.)	15·0	16·5	9·0	6·1

The results indicate that the different varieties behave differently towards application of fertilizers. N.P. 4 and N.P. 12 have given the highest percentage increase over the control and highest response per lb. of nitrogen. N.P. 775 and C-591 have shown no response to fertilizer application.

Roberts and Kartar Singh in their book on Punjab Agriculture have recommended that C-518 is specially suited for rich irrigated lands. The results of this experiment have also shown that C-518 is better than C-591 in rich soils and C-591 is better than C-518 in normal soils.

N.P. 775 is recently released from Indian Agricultural Research Institute. The behaviour of this variety towards manuring is not much known. In soils of lower fertility this variety is observed to respond to manuring.

In another experiment the results of fertilizing three different varieties of wheat are given in Table XII.

TABLE XII

Results of fertilizing three varieties of wheat

Variety	Yield of wheat in md./acre (average of 3 years)			Per cent increase over control		Response in pounds per lb. of N	
	No nitrogen (control)	20 lb. nitrogen per acre as sulphate of ammonia	40 lb. nitrogen per acre as sulphate of ammonia	20 lb. nitrogen per acre	40 lb. nitrogen per acre	20 lb. nitrogen	40 lb. per acre
	Basic dose of P_2O_5 and K_2O						
N.P. 165	10·68	14·03	14·16	30·4	32·6	13·7	7·14
N.P. 710	10·98	13·48	14·73	22·8	34·1	10·25	9·37
N.P. 771	9·92	12·50	12·97	26·0	30·8	10·50	6·25

It will be seen that the different varieties have shown different performances. At the level of 20 lb. nitrogen N.P. 165 is better than the others. At the level of 40 lb. nitrogen all appear to be equal, though N.P. 710 indicates slightly better performances.

TABLE XIII

Effect of ammonium sulphate at two levels on wheat varieties N.P. 165 and C-518

Variety	Yield of wheat grain in md./acre (average of 2 years 1950-51)		Per cent increase over control	Response in pounds per lb. of nitrogen
	No manure (control)	20 lb. N per acre		
N.P. 165	18·61	19·67	5·7	4·35
C-518	14·21	17·46	22·9	13·32

In still another experiment with N.P. 165 and C-518 responses as shown in Table XIII were obtained with the application of 20 lb. of nitrogen per acre as sulphate of ammonia.

The two varieties have behaved differently, C-518 responding more than N.P. 165.

The results of the above-mentioned experiments have shown that manuring practices would vary with the variety. Some need higher rate of manuring while others need smaller rate of manuring. There are still others which may not even respond to manuring. Lamb and Salter [1936] in *Journal of Agricultural Research* **(53)** on pages 129-143 have said that varieties respond differently to series of fertility levels. Gardner [1950] in *Agriculture*, **LVII(1)**, pages 1-8, states that different varieties of wheat respond differently to manuring.

The findings in this paper also agree with these and other workers.

It will be necessary to test the findings in different tracts to prepare a proper schedule of manuring.

Sowing date response to nitrogenous fertilizer

In an experiment which was in progress since 1949-50, wheat crop was sown n 20 October, 15 November and 10 December. The crop was manured with 0,20 and 40 lb. nitrogen as sulphate of ammonia. The summary of results is given in Table XIV.

Table XIV

Sowing date response to nitrogenous fertilisers

Sowing date	Yield of wheat in md./acre (Average of 3 years 1949-52)			Percentage increase over control		Response in pounds per lb. of nitrogen	
	No manure (control)	20 lb. N/acre	40 lb. N/acre	20 lb. N	40 lb. N	20 lb. N/acre	40 lb. N/acre
A. 20 October	9·84	12·73	13·75	29·4	39·8	11·8	8·0
B. 15 November	11·19	14·48	15·40	29·4	37·6	13·5	8·5
C. 10 December	10·88	12·72	12·90	17·0	18·6	7·5	4·1

The economics of fertilizing wheat when sown on different periods is shown in Table XV.

Table XV

Economics of fertilizing wheat

Sowing date	Economics, i.e. Profit (+) Loss (—)	
	20 lb. N/acre	40 lb. N/acre
A. 20 October	+27·63	+24·87
B. 15 November	+33·53	+30·05
C. 10 December	+9·75	—7·16

It would be seen from the figures in Table XIV that the 15th November is the optimum date for sowing wheat. The yield of wheat is reduced when sown either earlier or later. Application of 20 lb. nitrogen per acre can help to either advance or extend the wheat sowings. It is also clear that wheat crop when sown either early or late would need higher doses of nitrogen than wheat crop sown during the optimum period. It will be seen from Table XV that maximum net profits are obtained from fertilizing wheat sown during the optimum period, followed by earlier sowing, i.e. the 20th October and later sowings, i.e. the 10th December. Late sowings have given least economic returns and in fact higher dose of nitrogen has proved to be slightly uneconomical.

It is thus seen that the fertilizing wheat with nitrogen has to be adjusted according to the period of sowing.

Fertilization of wheat in different rotations

Different croppings affect the soil productivity differently. In an experiment on response curve of nitrogen with wheat, the following cropping was observed :—

I	1948	1949	1949
	Rabi	*Kharif*	*Rabi*
	Berseem	Fallow	Wheat
II	1949	1950	1950
	Rabi	*Kharif*	*Rabi*
	Wheat	Fallow	Wheat
III	1949	1950	1950
	Rabi	*Kharif*	*Rabi*
	Jowar harvested in November, December and again sown for fodder in March.	*Jowar* harvested in July for fodder.	Wheat

The results of the response of wheat under the three croppings are summarised in Tables XVI, XVII and XVIII.

Table XVI

Response of wheat C-518 to nitrogenous fertilization in the rotation of berseem-fallow-wheat

(Cropping I)

Treatment				Yield of grain in md./acre	Per cent increase over manure	Response in pounds per lb. of N in presence of P_2O_5 and K_2O
	N	P_2O_5	K_2O			
A.	0	0	0 (no manure)	27·17	..	..
B.	0	60	40 (control)	29·60	8·8	..
C.	10	60	40	37·70	38·7	86·3
D.	20	60	40	33·87	24·6	27·5
E.	30	60	60	30·30	11·5	8.5
F.	40	60	40	30·82	13·4	7·5
G.	50	60	40	29·43	8·3	3·7
H.	60	60	40	29·60	8·8	3·3
I.	70	60	40	27·34	0·6	0·2
J.	80	60	40	27·84	2·4	0·7
K.	90	60	40	28·20	3·8	0·9
L.	100	60	40	27·60	1·5	0·4

'F' test—Not significant

TABLE XVII

Response of wheat C-518 to nitrogenous fertilization in the rotation of wheat-fallow-wheat

(Cropping II)

Treatment				Yield of wheat grains in maunds per acre	Per cent increase over no manure	Response in pounds per lb. of nitrogen in presence of P_2O_5 and K_2O
	N	P_2O_5	K_2O (no manure)			
A	0	60	40	20·46		
B	0	60	40	21·03	2·8	
C	10	60	40	22·28	8·9	15·9
D	20	60	40	28·11	37·4	31·4
E	30	60	40	29·40	43·7	24·4
F	40	60	40	28·71	40·3	16·9
G	50	60	40	31·23	52·6	17·8
H	60	60	40	31·10	52·0	14·5
I	70	60	40	29·38	43·6	10·4
J	80	60	40	36·11	76·5	16·0
K	90	60	40	33·50	63·7	11·9
L	100	60	40	35·86	75·3	12·6

'F' test—Significant

C. D. at 5 per cent—34·92

TABLE XVIII

Response of wheat C-518 to nitrogenous fertilization in the rotation of jowar-early fodder-jowar-wheat

(Cropping III)

Treatment	N	P_2O_5	K_2O	Yield of wheat grain in md./acre	Per cent increase over no manure	Response in pounds per lb. of nitrogen in presence of P_2O_5 and K_2O
A	0	0	0	15·54		
B	0	60	40	17·24	10·9	
C	10	60	40	21·27	36·9	47·0
D	20	60	40	23·74	52·8	33·6
E	30	60	40	25·78	65·9	28·0
F	40	60	40	32·57	109·6	34·9
G	50	60	40	29·74	91·4	23·5
H	60	60	40	29·77	91·6	19·4
I	70	60	40	31·87	105·1	19·1
J	80	60	40	36·80	136·8	21·8
K	90	60	40	39·20	152·3	21·5
L	100	60	40	37·19	139·3	17·0

'F' test—Significant

C. D. at 5 per cent.—5·65

It will be seen from the figures in Table XVI, XVII and XVIII that highest yield under control was obtained under cropping I followed by cropping II and III.

It is also clear that in the three croppings the responses to nitrogenous fertilizer treatments have been different. In cropping I, the application of nitrogenous fertilizer have shown the least effect and in cropping III the effect has been the highest.

It is thus clear that in high productive soils like that in cropping I, application of nitrogenous fertilizers is either not necessary or small doses of nitrogen would be necessary. In soils of low and poor productivity such as in those cropping II and III, application of nitrogenous fertilizers gives high returns and helps in pushing up yields.

It may, therefore, be said that soils of poor or low productivity will show better response to the application of nitrogenous fertilizers.

Effect of nitrogen, P_2O_5 and K_2O

This was a part of mixed cropping experiment conducted in 1948-49 and 1949-50. It included studies on the effect of nitrogen and P_2O_5 alone and in combination. The variety of wheat sown was C-518. Soil was light in texture and its chemical composition was of the following order :—

Total nitrogen (per cent)	Total P_2O_5 (per cent)
0·052	0·0977

The summary of average results for the years is given in Table XIX.

Table XIX

Summary of average results about N and P_2O_5 treatments and their combination

Treatment	Yield in md./acre (average of 2 years)	Per cent increase over control	Economics Profit (+) Loss (—) in rupees per acre
A. No manure (Control)	23·00		
B. 40 lb. nitrogen as sulphate of ammonia per acre	28·40	23·5	50·3
C. 60 lb. P_2O_5 per acre as superphosphate	28·65	24·6	54·5
D. 40 lb. nitrogen+60 lb. P_2O_5 per acre	35·75	55·4	135·3
E. 60 lb. P_2O_5+40 lb. K_2O per acre	26·95	17·2	5·7
F. 40 lb. nitrogen+60 lb. P_2O_5+40 lb. K_2O per acre	35·60	54·8	111·7

It will be seen from the figures in Table XIX that the application of both nitrogen and P_2O_5 is necessary in this particular soil. When these are applied alone, each nutrient has given nearly the same increase and economic return. When both these nutrients were combined together, increase had risen from about 24 per cent to 55 per cent and profits rose from about Rs. 52 to Rs. 135 per acre. It is thus clear that the efficiency of nitrogen can be enhanced when applied with P_2O_5.

It is also clear that the application of K_2O has shown no beneficial effect but it has produced depressing effect and reduced profit. The application of K_2O is therefore not necessary.

Summary and conclusions

The results of various experiments on manuring of wheat during 1948-52 have been summarised. From the results following conclusions are drawn.

1. The nitrogen is the dominant requirement for wheat.

2. Nitrogen can be supplied to wheat in any of the following forms : farm yard manure cake, green manuring and artificials.

3. The optimum dose of farm yard manure appears to be 10-15 tons per acre or 100 lb. of nitrogen per acre applied 7-8 weeks before sowing. The exact time of application of farm yard manure, however, needs to be studied in details.

4. The optimum dose of groundnut cake is 40 lb. nitrogen per acre. The possibility of lower dose needs to be studied.

5. Green manuring with sannhemp or *guar* gives the same results. The practice of green manuring appears to be the cheapest source of nitrogen for wheat.

6. Different forms of nitrogenous fertilizer, viz. ammonium sulphate, ammonium nitrate, Chilean nitrate and urea, help in increasing yield of wheat. They are all good carriers of nitrogen. Urea has however, shown slightly lower trends.

7. The optimum dose of nitrogenous fertilizer is 20 lb. nitrogen per acre.

8. The best time of application of nitrogenous fertilizers appears to be with first irrigation. This, however, is still under experimentation.

9. The presence of sufficient quantity of P_2O_5 increases the efficiency of nitrogen. The application of nitrogen in presence of P_2O_5 has shown better response. From the data available so far it appears that the combination of nitrogen and P_2O_5 in the ratio of 2 : 3 would be proper.

10. The different varieties do not give the same response to manuring. C-591 and N.P. 775 varieties do not respond to application of nitrogenous fertilizers under the condition of the experiment. N.P. 12 and N.P. 4 give the highest response to the application of nitrogenous fertilizers. C-518, C-228, N.P. 165, N.P. 710, N.P. 718, N.P. 80-5 are some of the varieties which respond to nitrogenous fertilizers.

11. Manuring of wheat has also to be adjusted according to the period when the crop is sown. Higher application of nitrogen would be necessary when sown out of optimum period.

12. The manuring practices would vary with the productivity of the soil. Soils low in productivity would need higher rate of manuring than soils high in productivity. Soils of low productivity will however show higher percentage increase and response. The manuring practices would thus help in pushing up yields of soils of low productivity.

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PRELIMINARY STUDIES ON THE RELATIVE VALUE OF DIFFERENT* FORMS OF COMMERCIAL NITROGENOUS FERTILIZERS

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UNDER Indian conditions, nitrogen is the most important limiting factor in crop production. It is therefore necessary to supplement nitrogen in the soil to raise a normal crop. Nitrogen is applied to the soil in various forms. One of the form in which nitrogen is being applied is the commercial fertilizer. The nitrogen in the commercial fertilizer is now available in many forms such as sulphate of ammonia, urea, ammonium nitrate, sodium nitrate, etc., but there is very little information available on the relative value of nitrogen in different commercial fertilizers. The use of these fertilizers is on the increase and the country has also started manufacture of nitrogenous fertilizers. It is therefore necessary to know the relative value of various commercial fertilizers in the market, both from the point of view of increased production and national planning of manufacture of commercial nitrogenous fertilizers.

With this view in mind an experiment was started in 1949-50 in the Division of Agronomy. The crop under study was wheat. The results obtained are described in the following pages.

Historical background

The practice of manuring for increased crop production has been in vogue from ancient times. The use of commercial nitrogenous fertilizers has however been in vogue very recently. Collins [1946] states that the use of chemical fertilizers probably dates from 1665 when Sir Digby wrote that he had increased the yield of crops by application of saltpeter. Curtis [1942] states that the earliest nitrogenous fertilizer that was in use in days of Leibig was the ammonia from gas works and Leibig emphasized the conversion of the ammonia by converting it in the non-volatile sulphate by the treatment of ammoniacal liquor with gypsum. Collins [1946] states that the by-product of ammonium salts was first produced in England in 1840 and in 1893 in the United States of America. The exploitation of Chilean nitrate began by about 1830 in Europe and America. In the Nineteenth Century use of Chilean nitrate increased rapidly both in Europe and America. By 1900 there were only Chilean nitrate and ammonium sulphate available in the market. Following the World War I, there appeared many other commercial forms in the market.

* Shri L. L. Relwani, Research Assistant, assisted in 1949-50 and Shri S. K. Nigam, a post-graduate student took this problem for post-graduate studies during 1950-51 under the guidance of the author.

Curtis [1942] states that the most important commercial fertilizers were (i) calcium cyanamide, (ii) calcium nitrate and (iii) synthetic ammonium sulphate. The use of calcium nitrate and calcium cyanamide was, however, limited due to hygroscopity in the case of calcium nitrate and difficult handling in the case of calcium cyanamide. The products of synthetic ammonium sulphate increased considerably and monopoly of Chilean nitrate was broken. Germany at this stage brought in the market mixture of ammonium sulphate and ammonium nitrate, while the United States of America brought in the market ammoniacal superphosphate.

After the World War II, many more forms are now available in the market. The important ones however are (i) ammonium sulphate, (ii) Chilean nitrate, (iii) ammonium nitrate and (iv) urea. In India, there exists mines of crude potassium nitrate but use of this fertilizer has not been taken up probably due to its high cost. Vaidyanathan [1933] has shown that the use of commercial fertilizers probably dates from about 1882, when potassium nitrate and ammonium chloride were used at Kanpur. The use of Chilean nitrate and ammonium sulphate however dates from 1906 when these were used in the States of Bombay, Uttar Pradesh and Madhya Pradesh. In Madras these were probably first tested in 1909.

The trials with ammonium nitrate and urea in India are very recent. These fertilizers, however, are not in use on a large scale. Of all the commercial fertilizers, ammonium sulphate is the most common in use at present and it is now being manufactured in India at Sindri and other factories.

Material and methods

The experiment to study the relative value of different forms of commercial fertilizers was started in 1949-50 and was concluded in 1951-52.

There are many forms of nitrogenous commercial fertilizers available in the market. These are (i) Chilean nitrate (sodium nitrate), (ii) ammonium sulphate, (iii) ammonium nitrate, (iv) urea, (v) calcium cyanamide, (vi) ammonium chloride, (vii) calcium nitrate, (viii) nitro chalk and (ix) ammonium nitro sulphate. It was intended to test as many forms of nitrogenous commercial fertilizers as could possibly be done. Due to non-availability of all the forms, only four forms, viz. (i) Chilean nitrate (sodium nitrate), (ii) ammonium nitrate, (iii) urea and (iv) ammonium sulphate were tested. These were tested at two levels of nitrogen with no manure as control. The short description of different forms under test is as under.

Description of different commercial nitrogenous fertilizers under test

(i) *Chilean nitrate* (*sodium nitrate*). It has been used for the longest time of all the inorganic nitrogenous fertilizers. For over a century, the fertilizer was obtained from natural deposits in Chile and hence called Chilean nitrate. In recent years however, large quantities are being produced from synthetic ammonia and sodium carbonate. Chilean nitrate is now available in white granulated form and good mechanical condition. It contains 16 per cent nitrogen. Brenchley [1943]

reports that Chilean nitrate contains very small amounts of boron, magnesium, iodine and other rare elements.

Nitrogen in Chilean nitrate is available in the soluble form and thus easily available to the plant. It is very soluble and thus liable to loss by leaching.

Chilean nitrate is a neutral salt, but it is physiologically basic and therefore it has the power to reduce to some extent acidity of the soil and may thus be employed with additional advantage in acid soils if some form of lime is not used.

It is available in India. The approximate cost at Delhi would be Rs. 400 per ton or Rs. 1·125 per lb. of nitrogen.

(ii) *Ammonium nitrate.* It has come in the market after the World War II, in quantities, that would suggest that Chilean nitrate and ammonium sulphate will meet increasingly serious competition from the new source of nitrogen in the years immediately ahead. It is manufactured for use in the production of explosives and fertilizer purposes. Before World War II, very little of ammonium nitrate was made as commercial fertilizer.

The commercial product of ammonium nitrate contains 32·5 to 33·5 per cent of nitrogen. One-half of the nitrogen is in the ammoniacal form and the other half in the nitric form. It is entirely soluble in water. It is also quick acting nitrogen fertilizer. Ammonium nitrate is hygroscopic under humid conditions. The recent research on the manufacture of ammonium nitrate have, however, shown that the ammonium nitrate can now be put in the market in about as good a physical condition as that of sodium nitrate and sulphate of ammonia. When exposed to the atmosphere, ammonium nitrate by itself is regarded as hazardous material in that it is inflammable. Efforts are being made to produce this material in such a form so as to reduce this danger.

It is considered a concentrated form of nitrogenous commercial fertilizer and thus would bring savings in the cost of transport. It is now available in India. At Delhi its approximate cost would be Rs. 500 per ton or Re. 0·65 per lb. of nitrogen.

(iii) *Urea.* It has come into the market very recently. It is a synthetic product. Chemically urea is an organic compound. It can be classified as organic nitrogen source but as it is soluble, it is commercially classified with inorganic nitrogen sources.

Commercial urea is identical with urea found in animal vrine. It contains 46 per cent nitrogen, an amount greater than that found in any other commercial solid nitrogenous fertilizer. It is thus a very concentrated form of commercial nitrogenous fertilizer.

Urea is converted to ammonia and nitrate in the field easily and is then used by the plants. The continued use of urea is likely to make soils slightly acidic. The nitrogen of the urea is more resistant to leaching than nitrogen in sodium nitrate, etc.

It is now available in India. At Delhi the approximate cost is Rs. 720 per ton or Re. 0·74 per lb. of nitrogen.

(iv) *Ammonium sulphate.* The consumption of ammonium sulphate as fertilizer has now exceeded that of sodium nitrate, which for many years was the world's

principal source of nitrogen. Most of the sulphate of ammonia used is a by-product of destructive distillation of coal, bitumous shells and bones. Some quantities of this fertilizer are also being made by the synthetic process, etc. It contains 20-21 per cent of nitrogen. The nitrogen is in the ammoniacal form. At ordinary temperature solubility of ammonium sulphate in water is practically equal to that of sodium nitrate. Tidmore and Williamson [1932] have shown that the nitrogen of ammonium sulphate may be retained by the soil in a form which does not leach as readily as sodium nitrate. Ammonium sulphate is physiologically an acid and when added to the soil, it increases soil acidity. Till recently ammonium sulphate was imported into Indian Union. It is now being manufactured in the country and it is expected that by the end of 1953, about 4,00,000 tons of ammonium sulphate will be produced annually. The price is fluctuating. In 1952 the approximate price at Delhi was Rs. 450 per ton or Re. 1 per lb. of nitrogen.

Experimental details

(i) *Soil.* The soil of the experimental plot was in the Main Block 8 B, C, D (North) during 1949-50 and Main Block 5 C and D (South) during 1950-51 and 1951-52. The soil has sandy loam texture and was of average fertility. The chemical analysis of the top layer of 9 in. varied as under:

Item	Main Block 8 B, C, D (North)	Main Block 5 C & D (South)
1. Nitrogen (Total)	0·055 per cent	0·046 per cent
2. Available P_2O_5	0·018 per cent	0·0147 per cent
3. *p*H	8·0	8·1

(ii) *Treatments.* These were as under.

A-No fertilizer (control)

B-Ammonium sulphate at 20 lb. nitrogen per acre

C-Ammonium sulphate at 40 lb. nitrogen per acre

D-Ammonium nitrate at 20 lb. nitrogen per acre

E-Ammonium nitrate at 40 lb. nitrogen per acre

F-Chilean nitrate at 20 lb. nitrogen per acre

G-Chilean nitrate at 40 lb. nitrogen per acre

H-Urea at 20 lb. nitrogen per acre

I-Urea at 40 lb. nitrogen per acre

In the third year (1951-52) a basal dose* of P_2O_5 and K_2O at the rate of 60 lb. P_2O_5 and 40 lb. K_2O per acre was given to treatments B to I and treatment J having only 60 lb. P_2O_5 and 40 lb. K_2O was added, for comparison.

* Basal dose of phosphate and potash was added so that the inadequacy of P_2O_5 and K_2O, if any, might not be a limiting factor in response of different forms of commercial nitrogenous fertilizers.

(iii) *Layout.* It was randomized block system with seven replications during 1949-50 and eight replications during 1950-51 and 1951-52.

(iv) *Plot size.* In the first year it was 0·024 of an acre and in the subsequent two years it was 0·0166 of an acre.

(v) *Agricultural operations.* Wheat crop was sown in about the mid of November each year, N.P. 52 was sown in the first two years and N.P. 718 the third year. The fertilizers were applied as top dressing with the first irrigation after sowing.

(vi) *Climate.* The season in 1949-50 was the most favourable season for wheat. During 1950-51 there were heavy rains accompanied by storm during the end of March, which resulted in lodging of crops. During 1951-52, there was an unprecedented hail-storm on the 1st and 2nd of March which damaged wheat crop.

Experimental findings

The yield data obtained during the three years, i.e. 1949-52 is given in Table I.

Table I

The effect of different forms of commercial fertilizers on wheat

Treatments	Yield of wheat grain in maunds per acre		
	1949-50	1950-51	1951-52
A. No fertilizer (control)	18·44	16·83	11·64
B. Ammonium sulphate at 20 lb. N/acre	28·56	20·50	16·05
C. Ammonium sulphate at 40 lb. N/acre	30·14	22·49	15·36
D. Ammonium nitrate at 20 lb. N/acre	26·33	21·53	14·78
E. Ammonium nitrate at 40 lb. N/acre	23·57	24·94	16·75
F. Chilean nitrate at 20 lb. N/acre	25·04	22·22	14·67
G. Chilean nitrate at 40 lb. N/acre	23·39	24·69	16·96
H. Urea at 20 lb. N/acre	22·53	19·75	15·95
I. Urea at 40 lb. N/acre	21·70	22·65	15·42
J. P_2O_5 at 60 lb. + K_2O 40 lb. per acre	..	..	9·41
F. test	Significant at 1 per cent	Significant at 1 per cent	Significant at 1 per cent
SEm	±1·58	±0·77	±1·046
C. D. at 1 per cent	6·01	2·87	3·94
C. D. at 5 per cent	4·51	2·17	2·96

The average effect of different fertilizers has been worked out in Table II.

TABLE II

The average effect of different fertilizers

Treatments	Yield of grain (wheat) in maunds per acre			
	1949-50	1950-51	1951-52	Average
5 Control	18·49	16·83	9·41	14·91
1 Ammonium sulphate	29·35	21·50	15·74	22·20
2 Ammonium nitrate	24·95	23·24	15·74	21·31
3 Chilean nitrate	24·21	23·45	15·82	21·16
4 Urea	22·11	21·20	15·65	19·65
Significance	Significant at 1 per cent	Significant at 1 per cent	Significant at 1 per cent	
SEm				
C. D. at 1 per cent	5·19	2·49	3·41	
C. D. at 5 per cent	3·89	1·88	2·56	

It will be seen from Tables I and II that during 1949-50 application of nitrogen in different forms at both the levels has given higher yields than control, but statistically application of nitrogen at both the levels in the form of ammonium sulphate, ammonium nitrate and Chilean nitrate is superior to control. At the level of 20 lb. of nitrogen the order of merit is ammonium sulphate, ammonium nitrate, Chilean nitrate and urea. Statistically ammonium sulphate is superior to urea only. At 40 lb. level of nitrogen the order of merit is the same as in 20 lb. nitrogen, but ammonium sulphate is statistically superior to the rest. Statistically there is no difference between ammonium nitrate, Chilean nitrate and urea. Ammonium suulphate is, however, superior to all. During 1951-52, the figures in Tables I and II show that the application of nitrogen in all the forms and at both the levels has given significantly higher yields than the control. At the level of 20 lb. of nitrogen the order of merit is Chilean nitrate, ammonium nitrate, ammonium sulphate and urea. Statistically Chilean nitrate is superior to urea only. At 40 lb. level of nitrogen the order of merit is ammonium nitrate, Chilean nitrate, urea and ammonium sulphate. Statistically ammonium nitrate is superior to urea and ammonium sulphate which amongst themselves are statistically equal. Chilean nitrate is equal to ammonium nitrate and urea but statistically superior to ammonium sulphate. The average effect of Chilean nitrate shows superiority over ammonium sulphate and urea and similarity with ammonium nitrate. Urea is similar to ammonium sulphate and inferior to ammonium nitrate.

During 1951-52, the results in Table I and II show that the application of nitrogen in different forms at both the levels has given statistically superior yield than the control. At 20 lb. level of nitrogen the order of merit is ammonium sulphate, urea, ammonium nitrate and Chilean nitrate. The differences in the yield however, are not statistically significant. At 40 lb. level of nitrogen the order of merit is Chilean nitrate, ammonium nitrate, urea and ammonium sulphate. The differences in the yield are, however, not statistically significant. All the four forms have shown similar effect. The order of merit however, was Chilean nitrate (ammonium nitrate and ammonium sulphate) and urea.

The results of three years have indicated that all the four forms of nitrogenous commercial fertilizers are good carriers of nitrogen, urea however being slightly less effective than the rest. Generally, application of nitrogen at the level of 40 lb. dose in all the forms has shown higher yields per acre than the application of nitrogen at the level of 20 lb. per acre.

Response. To get an idea of the relative efficiency of different forms and doses of nitrogen, it is essential to work out the response. The data presented in Table III show the response in pounds of grain per lb. of nitrogen applied.

TABLE III

Response of nitrogen in different forms in pounds of grains per lb. of nitrogen

Treatment	Response in pounds of grains per lb. of nitrogen			
	1949-50	1950-51	1951-52	Average
B. Ammonium sulphate at 20 lb. N/acre	41·50	15·11	27·20	27·94
C. Ammonium sulphate at 40 lb. N/acre	24·00	11·67	12·20	15·96
D. Ammonium nitrate at 20 lb. N/acre	32·30	19·33	22·00	24·54
E. Ammonium nitrate at 40 lb. N/acre	10·50	16·71	15·00	14·07
F. Chilean nitrate at 20 lb. N/acre	27·00	22·20	21·55	23·58
G. Chilean nitrate at 40 lb. N/acre	10·00	16·19	15·40	13·86
H. Urea at 20 lb. N/acre	16·75	12·02	26·80	18·52
I. Urea at 40 lb. N/acre	6·70	11·99	12·30	10·33

The figures in Table III show that irrespective of the form, the response per lb. of nitrogen is greater with the application of 20 lb. of nitrogen than with 40 lb. nitrogen. The trend of response of different forms of nitrogen in different years is nearly the same as has been shown under yield of grain in the preceding pages. On the whole, urea has shown the least response and the remaining three have shown nearly the same response. Order of merit amongst three being, ammonium

sulphate, ammonium nitrate and Chilean nitrate. It can be thus said that all the four forms are good carriers of nitrogen, though urea amongst them is the least.

Discussion

The yield of wheat was highest in 1949-50 and lowest in 1951-52. On page 217 (vi) climate under different year has been described. It will be seen that there was most favourable season for wheat in 1949-50 only and thus highest yields of wheat in that year.

The season in 1951-52 was most unfavourable for wheat as there was unprecedented hail-storm. This damaged wheat crop and this has resulted in lowest yield.

The season of 1950-51 was rather an average season and this resulted in an average yield.

Effect of application of nitrogen

The application of nitrogen at both the levels gave significant increase over the control. The fact that wheat crop responded to the application of nitrogen shows that nitrogen in the soil was a chief factor influencing the yield. Davidson and LeClerae [1917], Burke [1925], Donean [1934], Russell and Watson [1940] and many others are also of the same opinion.

The increases due to the application of nitrogen in different doses over control in case of wheat in India have been reported by Vaidyanathan [1933], Allen [1933], Stewart [1947] and Reports of Division of Agronomy [1949 and 1950]. There are many others all over the world who have reported increase due to application of nitrogenous fertilizers.

The application of nitrogen at the rate of 20 lb. per acre, has given higher response than the application at the rate of 40 lb. nitrogen per acre. This is due to lesser response for the second dose of nitrogen, which resulted in lowering the total response in the case of dose of 40 lb. nitrogen per acre. According to law of diminishing returns, response for every additional dose will decline till the stage is reached when the additional dose will not produce anything more. The decline in the response for the increasing application of nitrogen was observed by Black, *et al.* [1947], Panse, *et al.* [1947], and Yates and Boyd [1950].

The application of nitrogen at 40 lb. level has given higher yields than the application at the level of 20 lb. nitrogen. The differences however, are not great and lie within the critical error.

The increase in yield due to higher dose of nitrogen has been noticed by Richardson, *et al.* [1933], Crowther, *et al.* [1937], Stewart [1947], Cowie [1948] and many others.

The fact that the application of 40 lb. nitrogen per acre has not given proportionate increase in yield as compared to 20 lb. nitrogen per acre, is explained by the law of diminishing returns.

Relative value of different commercial nitrogenous fertilizers

The results of three years have shown that the different forms of commercial nitrogenous fertilizers under test are good carriers of nitrogen and when applied to wheat crop, give significantly higher yields than the control. The different forms have given different yields but the differences are small. The order of merit has been as under :

Ammonium sulphate, ammonium nitrate, Chilean nitrate and urea.

Hall [1915] concludes that nitrate of soda affords better source of nitrogen for wheat, grasses, etc., and is of equal value as that of ammonium sulphate for potatoes, etc. White [1925] concludes from data of 40 years that when ammonium sulphate and Chilean nitrate are used, they do not show much difference. Harvey [1925] states that by adjusting hydrogen in concentration of a soil in respect of preferences of a given crop, one could show an apparent superiority of ammonium sulphate over Chilean nitrate and *vice versa*. Lipman, *et al.* [1931] found that yields had been higher with nitrate of soda than with the ammonium sulphate. Richardson and Frieke [1931] and Richardson and Gurmery [1933] working in South Australia observed that for wheat and barley, nitrate of soda gave the highest return and urea the lowest. Ammonium nitrate and ammonium sulphate were intermediate. Kelly [1933] showed that with wheat, Chilean nitrate showed better results than ammonium sulphate. Bordon [1935] in Hawaii observed that the carriers of nitrogen were influenced by the soil upon which they were used. No significant differences were found on slightly acid soils. On neutral and alkaline soils there was a favourable difference in favour of ammonium sulphate. Padden [1937] failed to find out any significant differences in the yield of cotton from different nitrogenous fertilizers. Niklas, *et al.* [1939] found that the effect of sulphate of ammonia and Chilean nitrate was about equal. Morgan and Jackson [1942] report that the yield differences between various nitrogenous fertilizers supplying equal amount of nitrogen were of insignificant magnitude. Skinner [1944] in reporting results of 23 cotton tests with different sources of nitrogen, has shown that the average yield was least in case of urea and there was hardly any difference in yields of ammonium sulphate, Chilean nitrate and ammonium nitrate. Anderson, *et al.* [1946] concluded that the rate of application of nitrogenous material had more effect on the yields of paddy than did the type of nitrogen carrier. Tisdale, *et al.* [1952] have shown that one source of nitrogen is generally as efficient as any other source when the soils were adequately supplied with potassium and limed properly. Calcium cyanamide was found to be some-what less effective than the other sources of commercial nitrogen.

Unpublished work at the Central Rice Research Institute, Cuttack, has indicated that the ammonium sulphate, ammonium nitrate and ammonium phosphate are all good carriers of nitrogen for paddy.

Vaidyanathan and D. Allen [1933], Panse, *et al.* [1947] have shown the effect of nitrogenous manuring in different States as under :

Madhya Pradesh. Average response of ammonium sulphate and sodium nitrate were 7·8 lb. and 5·8 lb. per lb. of nitrogen respectively. In another trial urea gave

response of only 3·3. In the trials in Bihar the response to ammonium sulphate and Chilean nitrate has been varying as under :

Response in pounds per lb. of nitrogen

Place	Ammonium sulphate	Chilean nitrate	Remarks
Sabour	9·4	17·4	Unirrigated
Patna	12·7	4·5	Unirrigated
Bikramganj	..	30·4	Unirrigated
Gaya	..	4·1	Irrigated
Banka	13·4	..	Irrigated

There was steady increase in the yield over the whole range (10 to 60 lb. N) of doses, but response per unit of nitrogen was maximum in the region of 20 to 30 lb. of nitrogen per acre.

In trials in Uttar Pradesh, sodium nitrate (Chilean nitrate) at the rate of 12 to 18 lb. nitrogen per acre gave an average response of 13·2 lb. per lb. of nitrogen in 13 trials. At Muzaffarnagar ammonium sulphate at the rate 8-16 lb. nitrogen per acre gave a response of 20·8 per lb. of nitrogen.

In irrigated trials in the Punjab, at Lyallpur and Montgomery, ammonium sulphate proved better than nitrate of soda, but at Hansi and Sirsa, the latter was as good as the former.

From above, it will be seen that nitrogen is a very essential element for increased production. There is not much research data available on the relative value of urea and ammonium nitrate. It may be said that all the forms of nitrogenous fertilizers are good carriers of nitrogen. The different forms under test are nearly equal in performance as regards effect on the yield of wheat grain is concerned. Slightly higher yields in the case of ammonium sulphate can be ascribed to the alkaline nature of the soil.

Economics

The discussion and the conclusions would be incomplete without the knowledge of economics of the effect of different treatments. In working out the economics, the cost of fertilizers, labour involved in the application of fertilizer and extra labour involved in harvesting, threshing, etc., has been deducted from the cost of increased yield of the produce, over the control. The fertilizers have been valued at the cost shown in the preceding pages, application at the rate of Rs. 1-8 per acre, the cost of labour engaged in harvesting, threshing, etc., the increased production at Rs. 2 per maund of grain and the value of grain and *bhusa* at Rs. 15 and Rs. 2 respectively.

The summary of results is given in Table IV.

TABLE IV

Economics of fertilizing wheat with different forms of commercial nitrogenous fertilizers

Treatments	Net profit in rupees per acre				Net profit in rupees per rupee invested			
	1949-50	1950-51	1951-52	Average	1949-50	1950-51	1951-52	Average
B. Ammonium sulphate at 20 lb. N/acre	150·06	44·75	94·92	96·58	3·60	1·55	2·73	2·36
C. Ammonium sulphate at 40 lb. N/acre	174·60	63·42	57·65	98·56	2·69	1·20	1·08	1·66
D. Ammonium nitrate at 20 lb. N/acre	128·07	70·38	71·37	89·94	4·23	2·94	2·83	3·33
E. Ammonium nitrate at 40 lb. N/acre	91·19	123·20	113·84	109·94	2·41	2·81	2·70	2·64
F. Chilean nitrate at 20 lb. N/acre	101·80	75·77	85·54	87·70	2·74	2·18	2·48	2·47
G. Chilean nitrate at 40 lb. N/acre	57·85	96·36	92·49	82·23	1·03	1·55	1·50	1·36
H. Urea at 20 lb. N/acre	70·87	39·08	108·80	72·92	2·90	1·77	3·70	2·79
I. Urea at 40 lb. N/acre	57·28	79·14	68·83	68·42	1·52	1·85	1·60	1·66

TABLE V

The overall economics of different forms of commercial fertilizers

Form	Average net profit per acre in rupees	Average net profit in rupees per rupee invested
1. Ammonium sulphate	97·57	2·01
2. Ammonium nitrate	99·94	2·98
3. Chilean nitrate	84·96	1·91
4. Urea	70·67	2·22

The figures in Table IV and V clearly indicate that the use of all the four forms of commercial nitrogen fertilizers has resulted in profit, which varies under the condition of the experiment, from about Rs. 70 to Rs. 100 per acre.

As regards net profit per acre the order of merit is indicated as under.

Ammonium nitrate, ammonium sulphate, Chilean nitrate and urea.

As regards profit per rupee invested, ammonium nitrate stands first, followed by urea, ammonium sulphate and Chilean nitrate. The use of all the forms has proved economical at both the levels, i.e., 20 lb. and 40 lb. nitrogen. The trend of profit per acre at different levels with different forms has been changing in different years, but it is however indicated that in case of ammonium nitrate, the net profit with 40 lb. nitrogen per acre is generally more than that in 20 lb. of nitrogen. In the case of the other three forms it can be said that the net profit is nearly the same with both the levels.

As regards net profit per rupee invested it decreases with higher dose. The use of 20 lb. of nitrogen per acre, therefore, brings more return per rupee invested.

The best performance of ammonium nitrate as regards profits, per acre and also per rupee invested, is due to the fact that the value of a pound of nitrogen in the form of ammonium nitrate is the lowest and necessitates lowest investment. Relatively smaller profits in Chilean nitrate are due to higher cost per pound of nitrogen, which necessitates higher investments.

These results indicate that the Chilean nitrate and ammonium sulphate will meet serious competition from ammonium nitrate, etc., unless the prices of the above two fertilizers are relatively reduced.

Summary

An experiment on the studies on the relative value of different forms of commercial nitrogenous fertilizers was started in 1949-50 and concluded in 1951-52. Four nitrogenous fertilizers, viz., ammonium sulphate, ammonium nitrate, Chilean nitrate and urea at two levels of 20 and 40 lb. nitrogen per acre were tested on wheat. The fertilizers were top-dressed with first irrigation. The effect has been studied on the yield of grain and response in pounds per lb. of nitrogen. Attempt has also been made to work out the economics. The results have been described in the foregoing pages and the summary of the results is as under :

1. The application of nitrogenous fertilizers gave significantly higher yields than the control in all the years. This indicates the necessity of application of nitrogen in the case of wheat.
2. The yields increased with higher dose of nitrogen, but the increase was not in proportion to quantity of extra nitrogen applied.
3. The different forms gave slightly different yields. The order of merit has been changing from year to year. It may, however, be said that urea gives the least yield of grain per acre and that there is practically no difference between the yields of the other three fertilizers though ammonium sulphate has given the highest yields of grain per acre.
4. All the four forms are proved to be good carriers of nitrogen and these have helped to increase yield of wheat from 25 to 40 per cent.
5. Ammonium sulphate has given the highest response followed by ammonium nitrate, Chilean nitrate and urea. Ammonium nitrate and Chilean nitrate are however equal. The response declined with the increase in the rate of application of nitrogen.

6. Application of nitrogen in all the forms and doses was profitable. Only in the case of ammonium nitrate, higher dose gave higher profit, while in the other cases the profits at both the levels were nearly equal. On the whole ammonium nitrate was the most profitable fertilizer as regards profit per acre was concerned followed by ammonium sulphate, Chilean nitrate and urea. As regards profit per rupee invested, the profit is more with the lower dose than that with the higher dose. Ammonium nitrate gives the highest profits at both the levels followed by urea, ammonium sulphate and Chilean nitrate.

Conclusions

The results of these experiments indicate that all the four forms of commercial nitrogenous fertilizers under test are good carriers of nitrogen and could be used as alternate source of nitrogen. Their use will, however, depend on easy availability of the material and its cost. With the present cost of ammonium sulphate and Chilean nitrate, it is indicated that these fertilizers will meet serious competition from ammonium nitrate, etc.

It is, however, very necessary to conduct long-term experiments under local conditions to determine the suitable form of commercial nitrogenous fertilizer for a given locality.

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UTILIZATION OF SOME NITROGENOUS WASTE MATERIALS AS MANURES

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THE low crop-producing capacity of cultivated lands in India constitutes a major practical problem in the development of agriculture in the country, and it has been repeatedly stressed that among the plans and programmes to step up production, the need for increasing the fertility of lands already under cultivation is urgent. Irrigation alone cannot be fully effective in increasing crop production. The average yields of irrigated crops are also low. Improved seeds developed by crop breeding cannot make a full contribution to production if the yields are limited by low soil fertility. There are indications that the nutritional value of food crops is somewhat impaired as a result of low fertility level of the soil in which they are produced.

The low level at which crop yields appear to be stabilized in India, is a result of removal from soils, of plant food nutrients by the growing of crops from year to year, without due attention to the replenishment of the soils. One of the most fruitful methods of improving the fertility status of soils, thus lies in the judicious use of manures and fertilizers which add to the soil essential plant nutrients that have been exhausted as a result of cropping.

The present status of the major plant food nutrients in Indian soils, specially with respect to nitrogen and phosphorus warrants serious efforts to mobilize all sources of such manures and fertilizers for meeting adequately the large requirements of the country. With the limited resources of raw materials for the production of sufficient quantities of synthetic fertilizers in the country, it would be fruitful to examine the possibilities of utilizing as manures large quantities of some of the unconventional nitrogenous waste materials like wool wastes, animal and human hair wastes, leather and tannery wastes, hoof and horn wastes and blood-meal, available in the country. Some of these wastes are now being utilized by composting them along with other wastes by the hot fermentation process. The object of this paper is to show how these materials could be chemically processed to a powdery form suitable for direct use in agriculture as concentrated organic nitrogenous manures with the original compounds of nitrogen transformed into more available forms for plant growth.

With the widespread deficiency of nitrogen in Indian soils, experimental evidence indicates that manures and fertilizers containing adequate amounts of mineralizable nitrogen alone could significantly increase crop yields. "It is well known that farm yard manure, the oldest and most widely used nitrogenous fertilizer shows a fertilizing value which is much smaller than should correspond to its total content of nitrogen if this were fully available. The continuous wheat plots on Broadbalk,

Rothamsted, have shown a utilization by wheat plants of 26 per cent of the total amount of nitrogen added as farm yard manure over a period of 47 years. Other investigators also give figures which though variable show incomplete utilization of manure nitrogen " [Jensen, 1931]. Experiments in this Institute showed that a dose of 7·5 tons of farm compost supplying 120 lb. nitrogen per acre was inadequate to give a significant increase in yield of wheat whereas 40 lb. N per acre as ammonium sulphate increased the yield by 240 lb. The subject warrants proper assessment of this specific role of such manures.

Manurial value of some nitrogenous organic waste materials

Blood-meal, which may contain 8-11 per cent nitrogen nas been used in agriculture as a profitable manure since a long time. Peterman in Belgium tested the fertilizing value of dried blood as compared with nitrate of soda and found that the nitrogen of dried blood was as readily available as in the case of former [Storer, 1897].

Horn shavings are reported to contain 12-15 per cent nitrogen. The major part of nitrogenous compounds in horn is in the form of keratine which does not readily decompose and is not directly assimilable by plants. Results obtained by Aiken in Scotland showed that when in the form of fine dust, horns decompose in the soil and act as a good nitrogenous manure for grain crops [Wheeler, 1914].

Wool waste consists of short broken fragments of wool which are rejected in the various processes of preparing woollen fabrics. The material is valuable in composition particularly with respect to nitrogen which it contains to the extent of 10-14 per cent. The rapidity of decomposition of this and similar types of other materials depends to a large extent upon the fineness of their division [Hall, 1915].

Leather-meal prepared from waste leather may contain 4-7 per cent nitrogen. Roasted or steamed leather-meal is generally used in the preparation of mixed fertilizers. The availability of nitrogen from steamed leather-meal is slightly more than that from roasted leather-meal [Collings, 1948].

The availability of nitrogen in fermented organic manures like farm yard manure and composts has been the subject of study by several workers. In a comprehensive set of nitrification experiments, Jensen [1931] found that even under optimum laboratory conditions, nitrogen in farm yard manure is nitrified rather slowly and never completely. The fraction transformed into mineral nitrogen utilizable by plants may be of the order of 13-32 per cent of the total during a period of 500 days. Over two-third of manure nitrogen is thus not available. The rate at which this may be liberated under field conditions may be too slow for short season crops to benefit much from their application unless fairly large doses are applied.

Materials and methods

Samples of the materials, horn shavings, hair waste, wool waste, leather waste, blood-meal, waste milk powder, meat-meal, tannery waste and farm yard manure were obtained for this study from various sources in the country.

The raw nitrogenous materials like wool waste, hair waste and horn-meal are ordinarily not in a suitable condition to be utilized as such for manuring purposes. The complex nitrogenous compounds which these contain, have been found to be of low availability to plants; this has limited their exploitation. Treatments for processing them were therefore designed with a view to reduce them to a suitable physical condition for application as manures as well as to increase the availability of plant nutrients contained in them. The following two treatments for processing the materials into manures were examined:

(i) Steaming under pressure of 25 lb. per sq. inch, and

(ii) Acidulation with 10 per cent sulphuric acid, drying and powdering.

Analyses of the materials

The materials studied were analysed for total nitrogen, phosphoric acid, potash and calcium. Total carbon was also determined and the carbon-nitrogen ratio computed.

Nitrification experiments

The materials were subjected to nitrification tests under optimum laboratory conditions to assess the availability of their nitrogen for plants. Some of the raw materials were also examined with their treated samples to determine the magnitude of action of the treatments given to these materials.

Pot culture experiments

Pot culture experiments were carried out in *rabi* 1951-52 to examine the effect of the materials on the growth and yield of wheat. Nitrogen in all the treatments was applied at the rate of 200 lb. per acre, except ammonium sulphate which was applied at the rate of 40 lb. N per acre as the standard dose for wheat. This treatment was included with a view to compare the other treatments for their relative availability of nitrogen.

Results

Chemical analyses of the materials

The chemical composition of the materials with respect to nitrogen, P_2O_5, K_2O and CaO contents along with their C/N ratio is given in Table I on page 230.

Wool, hair and horn wastes contained substantial amounts of nitrogen varying from 7·29 to 15·62 per cent, as compared to 11·68 per cent in blood-meal. The amounts of phosphorus and potash in the materials were generally small, indicating their use chiefly as nitrogenous manures.

Total carbon content in these organic materials was fairly high, varying from 28 to 52 per cent as compared to 19·6 per cent in farmyard manure. Due to high content of nitrogen in proportion, the C/N ratio of the materials was generally low

TABLE I

Chemical composition of some waste nitrogenous organic materials

No.	Material	N (Per cent)	P_2O_5 (Per cent)	K_2O (Per cent)	CaO (Per cent)	C/N
1	Horn shavings (raw)	14·53	..	..	..	..
	Horn shavings (steamed)	14·00	0·09	0·44	1·31	3·10
	Horn shavings (acid-treated)	10·24	0·05	0·28	0·22	4·21
2	Hair waste (raw)	9·22	..	..	..	..
	Hair waste (steamed)	9·06	0·10	0·22	1·51	2·91
3	Wool waste (raw)	13·76	..	..	..	..
	Wool waste (steamed)	13·73	0·15	1·32	0·58	2·02
	Wool waste (acid-treated)	12·27	0·15	0·51	0·67	2·20
4	Leather waste (steamed)	15·62	0·05	0·23	0·18	2·62
5	Tannery waste (steamed)	7·29	0·21	0·22	16·30	4·07
6	Blood-meal	11·68	0·17	0·31	0·56	3·79
7	Waste milk powder	5·07	1·38	1·22	5·75	7·85
8	Meat-meal	11·83	0·44	0·45	0·27	4·39
9	Farm yard manure	1·26	0·09	0·26	0·67	..
	Farm yard manure (steamed)	1·00	1·25	0·95	2·72	20·10

varying from 2·02 in wool waste to 7·85 in waste milk powder. This indicates their suitability for liberating available nitrogen for crop requirements. In comparison, the well decomposed farm yard manure tested in these experiments contained 1·26 per cent total nitrogen and had a C/N ratio of 15·5.

TABLE II

Progressive nitrification of manures

No.	Material		N in mg. N per 100 gm. soil after, Days				
			15	30	45	60	75
1	Control (soil)	NH3-N	0·84	2·02	2·24	..	..
		NO3-N	1·68	3·50	3·92	3·92	5·15
2	Blood-meal	NH3-N	3·08	1·30	..	..	..
		NO3-N	11·20	17·44	19·60	20·50	22·85
3	Hair waste (raw)	NH3-N	..	..	..	..	..
		NO3-N	5·60	5·60	5·10	5·30	5·30
4	Hair waste (steamed)	NH3-N	1·40	3·58	..	..	..
		NO3-N	3·92	4·22	11·76	11·75	11·76
5	Wool waste (raw)	NH3-N	3·80	..	..	..	..
		NO3-N	5·00	10·60	11·12	9·12	9·12
6	Wool waste (steamed)	NH3-N	2·52	1·79	..	..	..
		NO3-N	12·88	13·40	17·36	19·30	18·81
7	Wool waste (acid-treated)	NH3-N	..	..	..	..	..
		NO3-N	6·70	20·50	19·87	15·12	15·12
8	Horn shavings (raw)	NH3-N	..	..	..	..	..
		NO3-N	3·50	11·30	18·70	19·26	19·30
9	Horn shavings (steamed)	NH3-N	4·42	..	..	..	..
		NO3-N	9·19	13·08	18·48	23·52	23·60
10	Horn shavings (acid-treated)	NH3-N	..	..	..	..	..
		NO3-N	15·01	15·10	21·95	22·10	22·10
11	Meat-meal	NH3-N	7·56	..	..	..	..
		NO3-N	6·38	10·00	15·56	19·64	17·36
12	Waste milk powder	NH3-N	4·97	..	..	..	..
		NO3-N	1·23	7·14	9·94	9·94	13·57
13	Leather waste (acid-treated)	NH3-N	1·00	..	..	..	..
		NO3-N	5·00	5·60	7·17	4·82	4·82
14	Tannery waste (steamed)	NH3-N	..	..	..	..	..
		NO3-N	15·80	15·35	19·38	19·41	19·41
15	Ammonium sulphate	NH3-N	18·10	6·00	..	..	..
		NO3-N	6·50	14·00	29·60	26·08	26·08

Nitrification studies

The laboratory method of evaluation of nitrogenous manures is based on the decomposition of organic forms of nitrogen by soil micro-organisms and their transformation into ammoniacal and nitrate nitrogen when incorporated into the soil with optimum moisture content. Nitrification experiments carried out on the above lines enable evaluation of the comparative efficiency of different manures to supply available nitrogen for growing crops. Manures listed in Table I were added at the rate of 30 mg. nitrogen per 100 gm. of the soil and moisture was made up to 12 per cent. The soil-manure mixtures were kept in wide-mouthed bottles and moisture was maintained at the same level throughout the period of the experiment. Ammoniacal and nitrate nitrogen were determined in samples fortnightly. The determinations were continued for five fortnights and the results obtained are presented in Table II.

Blood-meal. Blood-meal nitrogen mineralized quickly to the extent of 14·28 mg. in the first fortnight. Additional 6·24 mg. of nitrate nitrogen were formed by the third fortnight. The rate of nitrate formation then dropped. The total nitrate nitrogen formed during the period was 22·85 mg. out of 30 mg. added, which works out to an availability of 76·1 per cent.

Hair waste. (*a*) *Raw hair waste.* This material proved resistent to decomposition and out of 30 mg. nitrogen added, only 5·63 mg. of nitrate nitrogen were formed during the first fortnight. No further mineralization was observed during the succeeding period. The availability of nitrogen worked out to 18·7 per cent.

(*b*) *Steamed hairwaste.* Steaming of hair waste at a pressure of 25 lb. per sq. inch for two hours enabled the material to be powdered after drying and nitrification experiments showed that 5·32 mg. of mineral nitrogen were formed during the first fortnight and additional 2·48 mg. and 7·54 mg. during the second and third fortnights. The total mineral nitrogen formed was 11·76 mg. which works out to an availability of 39·2 per cent.

Wool waste. (*a*) *Raw wool waste.* Wool waste like hair waste is not in a suitable condition in the raw state to be used as a manure and the untreated material yielded 8·8 mg. of mineral nitrogen after the first fortnight. Little decomposition took place thereafter and the total mineral nitrogen formed at the end of the period was 11·2 mg. giving an availability of 37·3 per cent. In the fifth fortnight a slight loss of nitrate nitrogen was noted.

(*b*) *Steamed wool waste.* Steaming of wool waste enabled the material to be powdered after drying and increased the availability of nitrogen considerably most of which was nitrified in the first fortnight. There was a slow liberation of nitrogen during the succeeding fortnights and at the end of the period a total of 19·3 mg. of nitrogen were transformed into nitrates, giving an availability of 68·3 per cent.

Horn waste (*a*) *Raw horn waste.* The material obtained was in the form of fine shavings. The nitrate nitrogen formed increased from 3·5 mg. in the first fortnight to 7·8 mg. and a further 7·4 mg. in the second and third fortnights. There-

after the rate dropped and a total of 0·43 mg. nitrate nitrogen was formed subsequently, bringing the total to 19·3 mg. The availability of nitrogen from the material works out to 64·3 per cent. This indicates that even in the raw condition horn shavings contained substantial amounts of available nitrogen.

(*b*) *Steamed horn shavings.* Steaming of the material, however, enabled it to be powdered which in nitrification experiments gave 13·6 mg. of nitrate nitrogen in the first fortnight and additional 3·39, 5·40 and 5·04 mg. in the succeeding determinations. The total availability of nitrogen in this case was 78·6 per cent.

(*c*) *Acid treated horn shavings.* Treating the material with 10 per cent sulphuric acid enabled it to be easily reduced to a powder after drying. In nitrification experiments this liberated 15·01 mg. of nitrate nitrogen. In the subsequent periods 0·09, 6·85 and 1·85 mg. of mineral nitrogen were formed, making the total to 22·1 mg. The availability of nitrogen worked out to 73·66 per cent.

Meat-meal. This commercial processed product made from waste meat mineralized to the extent of 13·9 mg. nitrogen during the first fortnight and further 3·6, 5·5 and 4·1 mg. during the subsequent intervals. The total availability works out to 65·1 per cent.

Waste milk powder. Nitrification tests with this material were undertaken at the instance of the Ministry of Agriculture. While it would not be feasible to obtain any significant quantities of this material for use as manure, the experiments showed that milk powder could yield 45·2 per cent of its nitrogen in mineralized form for plant use.

Ammonium sulphate. This fertilizer nitrogen was included in the nitrification experiments as a standard for comparison and the results showed that within the course of three fortnights, over 98 per cent of the added nitrogen was nitrified.

Leather waste. Tanned leather waste yielded a powdery material after soaking in 10 per cent sulphuric acid and subsequent drying but when subjected to nitrification, a total of 7·17 mg. nitrate nitrogen was formed out of 30 mg. nitrogen added during the five fortnights. The availability works out to 23·9 per cent showing that although inferior to other materials, the processed manure could still yield about one-fourth of its nitrogen for crop growth during five fortnights.

Tannery waste. Untanned leather waste from tanneries was more easily reduced to a powder by soaking in 10 per cent sulphuric acid and drying. In nitrification tests, formation of significant amounts of nitrate nitrogen was noted. The total availability at the end of five fortnights was 64·4 per cent.

Nitrification of farm yard manure

A detailed study of the availability of nitrogen in a sample of well rotted farm yard manure was undertaken with a view to assess the value of this type of organic manure for meeting the requirements of mineralized nitrogen for growing crops. The results of nitrification of the added nitrogen are given in Table III.

TABLE III

Nitrification of farm yard manure

(In mg. N per 100 gm. soil)

Treatments		Determination after, Days					Percentage nitrification
		30	60	90	120	150	
1. Control (soil)	NH3-N	2·70	..	..	..	..	..
	NO3-N	2·90	3·60	5·50	5·55	5·60	..
2. Soil (heat)	NH3-N	..	..	..	..	..	..
	NO3-N	3·60	2·79	5·50	5·55	5·60	..
3. Soil—F. Y. M. (heat)	NH3-N	..	..	..	..	..	..
	NO3-N	4·80	5·60	6·70	6·73	6·72	22·40
4. Soil—F. Y. M. (KMnO4)	NH3-N	0·22	..	..	..	..	..
	NO3-N	0·22	5·60	6·70	6·71	6·72	22·40
5. Soil—F. Y. M. (sulphur)	NH3-N	..	..	..	..	..	..
	NO3-N	6·60	6·60	6·71	6·72	7·00	23·33
6. Soil—F. Y. M. (lime)	NH3-N	1·60	..	..	..	..	..
	NO3-N	3·80	5·04	5·50	5·55	5·60	18·66
		15	30	45	60	75	
7. Soil—F. Y. M.	NH3-N	1·29	0·32	..	..	..	..
	NO3-N	0·22	1·50	2·32	4·50	6·00	20·00
8. Soil—steamed F. Y. M.	NH3-N	0·39	..	..	..	..	..
	NO3-N	0·56	0·60	0·70	0·65	0·60	2·33

Formation of mineral nitrogen from 30 mg. of manure nitrogen amounted to 6 mg. during five fortnights which works out to an availability of 20 per cent. The rate of nitrification was also slow indicating that adequate supplies of nitrogen may not become available for growing crops.

The treatment of farm yard manure with steam which proved so beneficial in the case of materials like hair, wool and horn wastes was found to considerably reduce the availability of F. Y. M. nitrogen. The total nitrate nitrogen formed amounted to only 0·7 mg. giving an availability of 2·33 per cent.

Other treatments designed to render nitrogen in farm yard manure more available included (*a*) subjecting soil-manure mixture to a temperature of 100°C. for four hours, (*b*) oxidising action of potassium permanganate added at 500 lb. per acre, (*c*) action of sulphur added at 2,000 lb. per acre and (*d*) action of caustic lime added at ten tons per acre. No appreciable difference in nitrification as a result of these treatments was observed showing that the nitrogen complexes in the manure were resistent to decomposition.

Pot culture experiments

Pot culture experiments were undertaken to test the effect of some of these manures on the growth of wheat and the uptake of available nitrogen. Yields of grain and straw obtained under the different treatments are presented in Table IV.

TABLE IV

Yields obtained under different treatments in pot culture experiments

Treatments	Total produce in gm.	Grain in gm.	Straw in gm.
Control	37·6	15·4	22·0
Ammonium sulphate	48·3	21·0	27·3
Blood-meal	69·1	29·8	39·3
Meat-meal	71·7	29·8	41·9
Milk powder	69·9	29·6	40·3
Hair waste—processed	56·2	25·3	30·9
Wool waste—processed	69·1	28·2	40·9
Horn waste—processed	62·4	26·5	35·9
Farm yard manure	58·1	24·0	33·9
Farm yard manure—steamed	14·4	6·4	8·0
Critical difference at 1 per cent	15·1	7·1	8·7

Manures prepared from hair, wool and horn wastes gave significant responses on wheat, indicating that the processing treatments could render them useful for utilization as nitrogenous manures. As already reported steaming of farm yard manure before application adversely affected its nitrification. Yields of wheat obtained with this confirmed the above result and showed that the treatment considerably reduced the effect of the manure on crop growth.

Wheat grain and straw from the different treatments were separately analysed for nitrogen and the percentage of manure nitrogen utilized by the crop was calculated (Table V).

TABLE V

Analysis of wheat grain and straw obtained under different treatments

Treatment	Per cent N in grain	Per cent N in straw	Total N in crop (in mg.)	Per cent of manure N recovered
Control	1·26	0·15	227·8	..
Ammonium sulphate	1·54	0·22	404·2	66·6
Blood-meal	2·83	0·47	1064·1	64·4
Meat-meal	1·98	0·25	724·2	37·5
Milk powder	2·13	0·49	777·2	41·4
Hair waste	1·54	0·34	535·2	23·2
Wool waste	2·65	0·44	930·8	53·1
Horn waste	2·75	0·48	938·8	57·4
F. Y. M.	1·72	0·21	563·1	20·82
F. Y. M. (steamed)	1·71	0·19	135·3	..

The results showed that in the presence of adequate nitrogen in the soil, nitrogen content in grain increased from 1·2 per cent with corresponding increase in yield upto a concentration of 1·98 per cent. Above this level, the concentration of nitrogen further increased to 2·8 per cent without any significant increase in yield. With steamed farm yard manure however, concentration of nitrogen in grain and straw was higher than in the unmanured crop which would indicate that under defective supplies of nitrogen, the crop struggles to mobilise the small amounts of available nitrogen to complete its life cycle by severely restricting its growth.

Total uptake of nitrogen by the crop under the treatments farm yard manure, ammonium sulphate and hair waste was more or less of the same order showing that the efficiency of 200 lb. of nitrogen as farm yard manure and hair waste was equal to that of 40 lb. nitrogen as ammonium sulphate.

The fraction of manure nitrogen utilized by the crop was the lowest for farm yard manure, confirming the result obtained in nitrification experiments that the major part of manure nitrogen is present in complex forms and about 20 per cent of this would actually be effective as plant food. Processed wool and horn wastes

on the other hand yielded over 50 per cent of their nitrogen to the crop with substantial effect on its growth and yield. The nitrogenous compounds in processed hair waste were comparatively less available and yielded 23 per cent of the added nitrogen. This material is under further examination for a more effective processing treatment.

Summary

The exploratory study carried out with a view to exploit nitrogenous waste materials available in the country for use as manures shows that by simple processing treatments, wool, hair, horn, leather and tannery wastes can be reduced to a powdery form and utilized with benefit as nitrogenous manures. Nitrification and pot culture experiments showed that the prepared manures could provide substantial amounts of nitrogen for crop requirements and significantly increase the yield.

The experiments on the availability of nitrogen in farm yard manure confirmed the observations reported by other workers that about 20 per cent of the manure nitrogen is actually utilizable by crops, implying the need for application of a minimum dose of 10 to 20 tons of the manure per acre to obtain a response corresponding to 40 lb. of fertilizer nitrogen per acre.

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A FIELD EXPERIMENT ON NATURAL GRASSLAND IN THE FORMER BARODA STATE

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GRASSLANDS constitute the mainstay of animal nutrition in India—about 90 per cent of the cattle are estimated to subsist on these. It, therefore, needs no emphasis that if the livestock is to be maintained in a reasonable state of efficiency, all efforts must be concentrated on increasing the productivity of grasslands [Royal Commission on Agriculture in India, 1929]. The Famine Inquiry Commission of 1940 further recommended to undertake experiments on reseeding and manuring of grasslands and other management practices. In spite of its national importance, grasslands till recently, did not attract sufficient attention from research workers. Beyond the pioneering work of Burns and his co-workers from 1921 to 1931, followed up by Kumar and Godbole [1939] on the improvement of grassland in Bombay State, and that by Mahta and Dave [1931] in Madhya Pradesh in addition to some work in U. P.; information on effects of different methods, like reseeding, manuring, etc. on the improvement of grasslands in India is practically not available.

The problem of grassland improvement in Baroda State was prominently felt early in 1930, in view of the gradual deterioration of reserved *zinzvo* (*Dichanthium annulatum*) grasslands, belonging to the *khanagi* and Military Departments, owing to the encroachment of coarser and undesirable *khadi* grass (*Chrysopogon montanus* var. *Robusta*). Preliminary trials conducted at Nimetta Beeds by the State Agriculture Department, on eradication of *khadi* grass and improving the yield by application of manures, proved promising. With the financial aid of the Indian Council of Agricultural Research a scheme was put up for the 'Improvement of Pasturelands in Baroda State' which, amongst other projects, included a large-scale field experiment on natural grasslands to study the comparative influence of different manures on the betterment and yield of desirable hay, in combination with cultural treatments for the eradication of *khadi* grass. The present paper gives a consolidated data on this subject obtained during the course of four years from 1943 to 1947.

Site, plan of layout and treatments

The present work was carried out at Bakrol Cattle Breeding Farm, about ten miles east of Baroda city. Out of a total of about 2,000* *bighas* of hay lands at the disposal of the farm, 80 *bighas* were taken up for the experiment. These were divided into four main blocks of 20 *bighas* each. Each main block was further divided in one direction into five strips corresponding to five manurial treatments, and in the other into four strips corresponding to four treatments of *khadi* removal. Each series of treatments were randomised. The design of experiment thus adopted

* 1·7 *Bighas*=1 Acre

was a strip plot design with eight replications. Of the four main blocks, two were cut for hay only, while the other two were grazed for the aftermath after the cutting of the hay. The details of the treatments were as below :

Manurial treatments

A. Groundnut cake 14 lb. N per *bigha*

B. Bone-meal 50 lb. P_2O_5

C. Groundnut cake 14 lb. N+Bonemeal 50 lb. P_2O_5

D. Farm yard manure 14 lb. N

E. No manure

Cultural treatments

X. Plots cleared once of *khadi*

Y. *Khadi* annually cleared

Z. *Khadi* annually cleared and reseeded with grass seed after harrowing

T. Entirely ploughed and reseeded

General history of the experimental area

The area selected originally belonged to the *khangi* and Military Departments of the Baroda State and was for several years being used as a hay land, grazing being permitted only after the harvest of grass in November-December. Harvesting of the grass, generally, was done through local contractors. *Khadi* being particularly unpalatable for horses used to be left undisturbed while other grasses, mainly *zinzvo* (*Dichanthium annulatum*), were cut. This long existed practice, gave an added advantage to the spread of *khadi*, the heavier seed with self burrowing mechanism further determined the successful invasion by this grass.

The experimental plot, was slightly sloping towards the west merging into the *Timbi* tank and except for few smaller veins and scattered pits, the land could be said to be fairly uniform. The Main Block III was situated rather on the low side and was subject to flooding after heavy downpours. The soil was black heavy loam throughout the area.

Precipitation

The annual mean precipitation of this tract is 49·0 inches, the maximum rainfall occurring in July and August, with few showers in September. In 1944-45 a total of 54·8 inches of rainfall was recorded. Rains commenced in early July and continued to pour down till August end with 11·54 inches in September. This continued rains immediately following the manurial application masked the effect of different manures to a certain extent.

In 1945-46 the rain, in general, was fairly well distributed during the growing season. The effect was reflected in the almost double yields compared to those in

previous years. Towards the close of the monsoon, exceptionally heavy showers amounting to 23·60 inches were received in 72 hours. The whole area, in particular the Block III, remained submerged under water for about a week. This flooding caused considerable damage to the crop. The total rainfall recorded was 57·62 inches.

In 1946-47 although normal precipitation of 49·95 inches was recorded, the distribution was very unfavourable. The monsoon commenced normally in the third week of June, the month registering 7·11 inches. The month of July which normally records maximum precipitation, recorded only 12·81 inches, with a dry period of 13 days commencing from the second week. This dry period affected the crop, severely damaging many of the young seedlings of annual species. The continuous wetty conditions during August, i.e. during the flush period of growth with a total of 25·53 inches in 28 rainy days, further retarded the growth of the crop. The mature crop presented a stunted and sickly appearance and consequently greatly affected the general yields.

Ecology of grasslands in the tract

The plot under study represents a typical grassland of the black soil in this tract with *Dichanthium annulatum* as constituting the economic climax species associated with such annual grasses as *Ischaenum rugosum* and *Themeda triandra*. Other grasses entering into the composition are *Desmostachya bipinnata*, *Iseilema laxum*, *Apluda aristata*, *Heteropogon contortus* and *Andropogon punilus*. The leguminous species are represented by *Indigofera hirsuta*, *Alysicarpus rogosus* and *Rhyncosia* species. The dominant tree vegetation was represented by *Butea frondosa*.

Depending upon the moisture content of the soil the succession takes up one of the two courses. With increasing moisture content the *Dichanthium* type gradually merges into a well defined *Iseilema* type in which *Iseilema wightii* constitutes the dominant species. With decreasing moisture content *D. annulatum* is replaced by *Chrysopogon montanus* (Robust form). The succession in this tract does not appear to have proceeded beyond the *Chrysopogon* stage, as *Sehima sulcatum* and *S. nervosum* which finally dominate the black soils in Berar, were not noticed in this tract.

A detailed survey of the vegetation (appendix I) revealed a total of 44 plant species out of which 26 were grass species. While ten of the grass species entered into the general composition only four species contributed substantially towards the bulk of the hay. These according to frequency of distribution were *torona* (*Ischaemum rugosum*) 65 per cent, *zinzvo* (*Dichanthium annulatum*) 16·5 per cent, *bhatadi* (*Themeda triandra*) 11·8 per cent, and *kadvi zinzvi* (*Eremopogon foveolatus*) 3·6 per cent, *D. annulatum* being a perennial species dominated the bulk of the hay.

Detailed composition of vegetation was studied by putting square meter list quadrats in each subplot on carefully selected spots representing the general vegetation. All the species enclosed within the frame were enumerated and the number of plants belonging to each individual species was recorded. These quadrat observations showed that only four species as noted above, stood out prominently and one

of these always assumed dominance, in the individual subplots. Table I gives the distribution of these species in each major blocks.

TABLE I

Distribution of dominant and subdominant species

Block	*Ischaemum rogosum*	*Dichanthium annulatum*	*Themeda triandra*	*Eremopogon foveolatus*	Rest
I	63/12	0/31	17/21	0/7	0/9
II	70/6	0/40	10/19	0/7	0/8
III*	45/8	1/29	7/5	2/6	0/7
IV	29/38	45/28	..	3/11	3/3

The figures represent the number of subplots, the denominator showing the dominance and numerator showing subdominance. Thus in the Block I, *Ischaemum rugosum* was dominant in 63 subplots out of a total of 80 and subdominant in 12 ; while *Dichanthium annulatum* was dominant in nil but subdominant in 31 plots and so on.

From Table I it will be seen that *Ischaemum rugosum*, an annual species was dominant in Block I, II and III, while alternatively *Themeda triandra*, again an annual, took up the position ; in each case, however, *Dichanthium annulatum* was subdominant. In the Block IV, however, *Dichanthium annulatum* was dominant leaving subdominance to *Ischaemum rugosum*. The vegetation thus, in general, was fairly uniform and gave an ideal condition to interpret the effects of different manures and other treatments.

EXPERIMENTAL PROCEDURE

The preliminary layout being completed in 1943-44 the experimental treatments commenced in 1944-45.

Cultural treatments

(*a*) Khadi *removal*. *Khadi* plants were dug out in the year 1943-44 from X, Y and Z strips by manual labour and were either burnt or were used in filling up bigger pits in the experimental area. Any plants coming up in Y and Z strips were removed annually. Strip Z was harrowed by hand-rake before the manurial and reseeding treatments in the first year. In the following years only reseeding was done in this strip. Strip T was entirely ploughed with tractor and harrowed with disc harrow in the first year before the manurial and reseeding treatments. No subsequent ploughing was given.

(*b*) *Reseeding*. The ploughed and harrowed strips T and Z respectively were reseeded in 1944 with a total of 304 lb. of mixed seeds of local nutritive grasses in

* Out of 80 only 55 subplots were studied.

the following proportion : *Iseilema wightii* (*machuri*) 160 lb. ; *Apluda varia* (*karedi*) 110 lb. and *Dichanthium annulatum* (*zinzvo*) 34 lb., the first and the third being perennials. The seed was supplied by the State Forest Department.

Owing to inadequate quantity of grass seed available for the experiment, the rate of reseeding, applied in the ploughed strips was only 10 lb. per *bigha* while in the harrowed strips a rate of 5 lb. was used. The seed was broadcasted.

In 1945-46 total seed available was 656 lb. comprising 414 lb. of *machuri* (*I. wightii*) and 242 lb. of *karedi* (*A. varia*). The rate applied in this season was *22 lb.* and 11 lb. per *bigha* in the ploughed and harrowed strips respectively.

In 1946-47 the total seed available was 840 lb. consisting of 280 lb. of *machuri* (*I. wightii*) 360 lb. of *bhatadi* (*T. triandra*) and 200 lb. of *zinzvo* (*D. annulatum*). The rate applied was 28 lb. and 14 lb. respectively.

Manurial treatments

The various doses of manurial treatments were based upon the preliminary experiments carried out at Nimetta. After analysis, the requisite quantity was broadcast in the respective strips before the commencement of monsoon in early June except in the year 1944-45 when owing to certain unavoidable reasons, the manures were broadcast in July after the outbreak of monsoon. Before application the groundnut cake was powdered.

Aftermath grazing

The aftermath grazing generally commenced a month after the harvest on the 1st of January, at the rate of one animal per *bigha*. The grazing continued till the end of April.

Grass cutting and hay yields

The respective plots were cut by hand labour generally in November when the grasses reached flowering stage. Each lot was weighed four days after cutting. The yield data obtained in each year was statistically analysed separately for manurial and cultural effects under ungrazed and aftermath grazed plots. The data from 1944-47 is presented in Tables II, III, IV and V.

Table II

Effect of different manures on the yield of hay in maunds per acre in ungrazed plots

Year of observation	Manurial treatments					Average	S. Em.	Critical difference	
	G. N. cake A	Bone-meal B	G.N. cake + Bonemeal C	F. Y. M. D	No manure E			at 1 per cent	at 5 per cent
1944-45	29·7	34·8	34·6	28·6	31·2	31·7	·046	5·81	4·31
Per cent increase over E	—4·8	11·5	10·8	—8·4					
1945-46	67·6	66·8	70·6	57·1	60·9	64·4	·024	8·98	6·66
Per cent increase over E	11·0	8·8	15·7	—6·3					
1946-47	42·3	42·8	43·8	41·6	37·4	41·6	·062	—	—
Per cent increase over E	13·1	14·5	17·2	11·2					
Average for 3 years	46·5	47·9	49·7	42·4	43·1	45·9			
Per cent increase over E	7·8	11·1	15·3	—1·7					

TABLE III

Effect of different manures on the yield of hay in maunds per acre in aftermath grazed plots

Year of observation	Manurial treatments					Average yields	S. Em.
	A G. N. cake 14 lb. N	B Bone meal 50 lb. P_2O_5	C G. N. cake + Bonemeal 14 lb.N 50 lb. P_2O_5	D F. Y. M. 14 lb. N	E No manure		
1944-45	24·5	27·9	29·6	25·2	23·3	26·1	0·080
Per cent increase over E	5·1	19·7	27·0	8·1			
1945-46	37·5	38·9	43·2	36·5	37·7	38·7	0·072
Per cent increase over E	—0·6	3·2	14·6	—3·2			
1946-47	31·6	33·5	30·7	31·7	29·4	31·4	0·075
Per cent increase over E	4·0	13·9	3·7	7·7			
Average of 3 years	31·2	33·4	34·5	31·3	29·8		
Per cent increase over E	4·6	12·0	15·7	4·8			

TABLE IV

Effect of cultural treatments on the yield of hay in maunds per acre in ungrazed plots

Year of observation	Cultural treatments					Critical difference	
	X *Khadi* cleared once	Y *Khadi* cleared annually	Z as in Y harrowed and seeded	T Ploughed and seeded	S. Em.	at 1 per cent	at 5 per cent
1944-45	35·7	35·7	34·8	20·7	0·055	8·63	6·52
1945-46	70·3	59·8	63·2	60·2	0·061	—	7·17
1946-47	41·5	38·8	45·0	38·0	0·057	—	—

TABLE V

Effect of cultural treatments on the yield of hay in maunds per acre in the aftermath grazed plots

Year of observation	Cultural treatments					Critical difference	
	X *Khadi* cleared once	Y *Khadi* cleared annually	Z as in Y harrowed and seeded	T Ploughed and seeded	S. Em.	at 1 per cent	at 5 per cent
1944-45	27·7	27·8	29·2	19·7	0·072	—	—
1945-46	41·3	41·6	40·8	30·7	0·065	9·34	6·75
1946-47	29·9	34·7	32·2	30·2	0·069	—	—

Chemical analysis

Samples of mixed hay under different manurial treatments were analysed in 1945-46. The analytical figures did not throw much light except that the plots treated with bone-meal showed a higher percentage of Ca than other treatments. In 1946-47 therefore, principal grass species were analysed in preflowering and flowering stages. The results are presented in Tables VI and VII.

Table VI

Effect of different manures on the protein content of three principal grass species in preflowering and flowering stages

Treatments	*Ischaemum rugosus*	*Themeda triandra*	*Dichanthium annulatum*	Average protein	Increase over control
			Preflowering stage		
A. Groundnut cake	4·38	3·68	4·08	4·05	24 per cent
B. Bonemeal 50 lb. P_2O_5	4·02	3·04	2·70	3·25	—
C. G. N. cake + bonemeal	3·97	3·91	3·08	3·65	12 per cent
D. F. Y. M. 14 lb. N	3·17	3·20	3·65	3·34	—
E. No manure	3·73	2·93	3·14	3·26	..
			Flowering stage		
A. Groundnut cake	2·43	2·95	2·83	2·74	17 per cent
B. Bonemeal 50 lb. P_2O_5	2·58	2·21	2·74	2·51	7 per cent
C. G. N. cake + bonemeal	1·91	2·48	3·67	2·68	14 per cent
D. F. Y. M. 14 lb. N	1·93	1·91	3·40	2·41	—
E. No manure	2·11	1·97	2·94	2·34	—

Table VII

Effect of different manures on the calcium and phosphorus contents of principal species in the flowering stage

Treatments	Constituents	*Ischaemum rugosus*	*Themeda triandra*	*Dichanthium annulatum*	Average
A. Groundnut cake	Cao	0·18	0·27	0·23	0·23
	P_2O_5	0·06	0·10	0·11	0·09
B. Bonemeal 50 lb. P_2O_5	Cao	0·15	0·20	0·32	0·22
	P_2O_5	0·22	0·16	0·15	0·18
C. G. N. cake + Bonemeal	Cao	0·14	0·22	0·22	0·19
	P_2O_5	0·20	0·21	0·24	0·22
D. F. Y. M. 14 lb. N	Cao	0·13	0·25	0·26	0·21
	P_2O_5	0·08	0·10	0·11	0·09
E. No manure	Cao	0·29	0·22	0·25	0·25
	P_2O_5	0·07	0·10	0·10	0·09

Discussion

The experiment was conducted to obtain information on three main aspects, viz. 1. The effect of application of different manures on the productivity of grasslands and the quality of the forage produced; 2. the effect of certain cultural methods, including partial or complete reseeding, adopted for the eradication of undesirable *khadi* grass (*Chrysopogon montanus*), in combination with different manures on the yield of hay, and 3. the effect of aftermath grazing in combination with the above mentioned treatments on the production.

The effect of manures on the forage production

From Tables II and III it will be seen that, in general, the application of manures showed beneficial response on the forage yield. The combination of groundnut cake and bone-meal gave the highest average yields with an overall increase of 15 per cent over the untreated plots. Bone-meal gave 11 to 12 per cent increase followed by groundnut cake with 4 to 7 per cent increase over the control. Although no statistical data were collected on the effect of manures on the composition of grassland, general observations showed that the plots receiving the phosphatic manure in the form of bone-meal, invariably indicated a better stand of *Alysicarpus rugosus*, a valuable legume component of Indian grasslands.

That grasslands respond remarkably well to manuring and especially to inorganic fertilizers, have been demonstrated by a very large number of workers. The bulk of opinion is in favour of the use of a combination of nitrogenous and phosphatic manures (4, 7, 12*) over either constituents. Better response due to combination of these ingredients was also shown in the studies at the Indian Agricultural Research Institute, New Delhi (6). Increased response of superphosphate in presence of groundnut cake has also been shown in the manurial experiments on grassland at Palghar (16).

The effect of manures was more prominently shown in the plots cut for hay only (Table II). Highly significant treatment differences were exhibited in the first two years. In 1944-45 bone-meal alone and in combination with cake gave highly significant increase over F. Y. M.—treated plots and proved significant over those treated with cake alone. The low yield under the cake treatment can be attributed to the late application of the manure, followed by continuous rainfall which probably caused the washing away of a part of the manure. In the subsequent years however, when the manure was broadcast before the commencement of monsoon, the effect was quite manifest and the yields were comparable to bone-meal treated plots.

In 1945-46, both cake and bone-meal, separately and in combination, gave highly significant yields over F. Y. M.—treated plots; cake alone and its combination with bone-meal giving respectively significant and highly significant increase over the control. No differences were exhibited between the superior treatments.

In 1946-47, the results were not significant but the same trends were indicated.

* The figures in the bracket denote references given at the end of the article.

The effect of the application of F. Y. M. was, in general, not favourable. In fact, in the first two years the response was negative. Positive response although not significant was observed only in the third year. The negative response indicated that a substantial part of the soil nitrogen was not made available to the growing grass crop but was possibly used up in the decomposition of the unrot organic matter of the F. Y. M. used. From the data obtained, however, the use of F. Y. M. in the improvement of grass lands, on back heavy loam soils of Baroda appears problematic. Negative response due to F. Y. M. was also observed by Bittera N. Von (3). Dung manure in combination with inorganic fertilizers has been shown by some workers to give better yields (9, 14).

Effect of aftermath grazing on the productivity of grassland

Although the manures indicated the same trends in the plots that were grazed for the aftermath, the treatment differences were not significant (Table III). The yields were, in general, lower in these plots compared to the ungrazed series. While in the latter the average yields increased to 103 per cent in the second year and by 31 per cent in the third year, the corresponding overall increase in the ungrazed plots was only 48 per cent and 20 per cent respectively. The aftermath grazing, therefore, appears to have adversely affected the vigour of growth in the following seasons to some extent.

These plots were generally grazed from the 1st of January to the end of April, the aftermath being mainly contributed by the perennial species *Dichanthium annulatum*. This lowering in the general productivity can be appreciated if the life-history of perennial grass is studied. It is well known that the underground parts of the perennial grasses contain an optimum quantity of storage food. This is drawn upon by the plant during the growing season till it begins to manufacture sufficient food material for its different physiological processes. The excess is translocated back to the underground parts, so that the optimum reserve is maintained at the beginning of each growing season (2).

Aftermath growth in the case of *Dichanthium annulatum* must have taken place at the expense of the stored food material. Owing to continuous grazing of the fresh growth, the plants did not get sufficient scope to rebuild their reserves which affected the general vigour of the plants in the following year. It, therefore, appears that instead of continuous grazing, which no doubt brought about complete utilization of the grass, an intermittent or deferred grazing with longer rest periods of about one month with lesser intensity of grazing would have probably proved better.

Effect of manures on the quality of forage

The grasses in this tract, in general, were poor in nutritive quality as shown by the low protein content of the species (Table VI). The calcium and phosphorus contents were also poor (Table VII). The examination of Table VI would show that the application of cake either alone or in combination with bone-meal considerably influenced the protein content and showed an average increase from 17 to 24 per

cent and 12 to 13 per cent respectively over the control. The effect of bone-meal was negligible and was slightly visible only in flowering stage. The increase in protein content due to application of readily available nitrogenous manures has been demonstrated by number of workers (1, 4, 10, 11, 13, 15).

There was no remarkable influence on the calcium content of the grass except that it indicated slight depression under manured plots. Depressed calcium content due to nitrogenous manuring has been observed by some workers (4, 8, 10, 19, 20). In the present investigation this depression was observed irrespective of manurial treatment and was more prominent under the mixture of cake and bone-meal (Table VII) and in the flowering stage. A higher phosphoric acid content, about twice as much as in the control and other treatments, was obtained where bone-meal was applied either alone or in combination with the cake.

Thus under the combination of cake and bone-meal the hay showed increased content of both protein as well as phosphorus. This treatment also showed the highest hay output. In general, therefore, manuring of grasslands has been beneficial both in improving the quality and quantity of the forage produced. The maximum response observed under the organic manures used was of the order of 15 per cent over the no manure plots. The use of nitrogenous fertilizer perhaps would prove still better as the nitrogen is more readily available in this form compared to the organic manures used.

Effect of cultural treatments on forage yield

The object of introducing the cultural treatments in the experiment was to study whether the different methods used for eradication of *khadi*, in particular the partial or complete reseeding treatments bring about any improvement in the yield.

Examination of Tables IV and V indicates that cultural treatments significantly affected the yield in the first two seasons in the ungrazed and in the second year in the aftermath grazed plots. In each case the plots which were entirely ploughed and reseeded with mixture of grasses, gave significantly less yield than the treatment where the plots were left comparatively undisturbed. No treatment differences were exhibited by the three superior treatments. The significance shown by the cultural treatments was, however, not genuine, as the reseeding with grass seed, which was a vital cultural treatment in the experiment, proved a complete failure.

Reseeding of grassland. In the reseeding treatment seeds of perennial as well as of annual grasses were included. *Iseilema wightii* (*machuri*) was considered to be suitable grass for this slightly wetty area. The effect of reseeding however was negligible. Plot observations showed that the ploughed strips were dominated by a stand of *Ischaemum rogosum* and *Themeda triandra*, grasses other than those included in the seed mixture. The presence of these grasses was explained as due to auto-seeding in the previous year and infiltration from the adjoining plots.

Some plants of *Dichanthium annulatum* were noticed but these were identified as belonging to the original cover. It was only in the third year that young seedlings of both *Iseilema wightii* and *Dichanthium annulatum* were observed. In general,

therefore, reseeding was a failure and thus the main basis of the cultural treatments was nullified.

These results find confirmation in the investigations of Burns (5) carried out in 1920-23 near Poona. In these experiments land considered as of worst type was ploughed and reseeded with a mixture of good wild grasses. His main observation on this experiment was, 'Reseeding is not a success in this area. The breaking up of the ground in this as in every other case which has come to our notice, results in a partial destruction of the existing grass cover.'

The results obtained in this experiment as also the experience of Burns, incidentally raise an important question as to the applicability or otherwise of the reseeding as a general measure for improving the natural grasslands in India. Two factors are involved in this measure, namely, 'the cultural practices necessary for seed-bed preparation and the quality of grass seeds used in reseeding. In the present investigations ploughing up of a well covered grassland followed by reseeding failed to establish a stand of better grasses; while ploughing itself brought about more or less complete destruction of the original cover.'

Ploughing up of a level land may not introduce many complications, but such an operation on a slopy land coupled with a failure of reseeding would invariably lead to disastrous consequences. Cultural operations, such as surface scratching, calculated to bring about least disturbance in the soil and to the existing cover may perhaps prove to be adequate for receiving the seed but considerable experimentation is needed on this aspect.

The second point involved in the reseeding treatment is the quality of seed utilized. One of the main difficulties with grasses, in general, is that the seeds generally mature at different periods and any attempt to collect the seed on mass scale becomes difficult as generally the ripe seed, which can alone ensure a good stand, is shed and what is collected is mostly immature seed. Further, knowing that the viability of grass seeds is generally poor, one can expect the quality of the so called collected seed. Grass seed collection is presumably a highly specialized job.

The reason why reseeding has been successful and is a sound practice in the U. K. and other pastoral countries is because there are organised firms dealing in seeds of forage crops. The result in the present experiment, although negative, is of great practical value, in that it clearly shows that in any pasture improvement programme recourse to reseeding should only be taken after ensuring the availability of pure guaranteed seeds.

Until the two factors described above receive sufficient attention from workers in the field, it is better to follow better management practices for improvement of grasslands such as stopping of the practice of selective cutting of *Dichanthium annulatum* in the present case or a complete closure to grazing for a few years.

Effect of cultural treatments on the control of khadi *grass*

From the number of *khadi* plants dug up from various treatments in February 1946, partially represented in Table VIII showed that a large number of *khadi*

plants were still present in the plots even after its removal successively in 1943 and 1944.

TABLE VIII

The number of khadi *plants per plot removed in February, 1946, in part of Replication III*

X	Y	Z	T
Khadi cleared only once	*Khadi* cleared annually	*Khadi* cleared annually and reseeded with five grasses	Entirely ploughed and reseeded
No record	125	421	23

Even the ploughed strips showed a fair number of *khadi* plants. The presence of such large number of plants, was due to the fact that *khadi* was not removed from the non-experimental area and hence served as a ready source of infiltration. These observations point out that the clearing of *khadi* grass, however thorough, from a part of the infested area, is no solution for its permanent eradication and hence the infested tract as a whole must be treated as a unit for eradication.

SUMMARY AND CONCLUSION

In the present paper are discussed the results of a field experiment on natural grassland carried out at the Cattle Breeding Farm, Bakrol, in the former Baroda State, from 1943 to 1947. The aspects included for study were; the effect of manures on the yield and quality of hay, aftermath grazing, reseeding of grasslands and methods for eradication of *khadi* grass (*Chrysopogon montanus* var. *Robusta*). The results on these aspects are summarised below.

1. The combination of phosphatic and nitrogenous manures in the form of bone-meal and groundnut cake respectively showed the highest significant response and gave 15 per cent increase in the average hay yields over the control.

2. Between the bone-meal and cake, the former yielded better although it was indicated that the timely application of the latter compared favourably with the former.

3. From the negative or poor response generally showed by farm yard manure, its use in the improvement of grasslands particularly on black heavy loam soils as at Bakrol, does not appear to be justified.

4. The effect of manures on the hay production was masked in the plots subjected to continuous aftermath grazing from the 1st of January to the end of April. Intermittent or deferred grazing with lower grazing intensity might have proved better.

5. The grasses in this tract were generally poor in nutritive value as shown by low contents of protein, calcium and phosphate. The application of cake and bone-meal separately increased the protein and phosphate contents of the hay respectively. The application of the combination of these manures was more

beneficial in that not only the protein and phosphate content in the hay was increased but also the hay production was more in this treatment.

6. Reseeding of grasslands with unreliable seed is apt to prove a failure and hence should not be recommended unless guaranteed seed stock is forthcoming.

7. Clearing of *khadi* grass (*Chrysopogon montanus*), however thorough, from a part of the infested area is no solution for its permanent eradication and hence the infested tract as a whole must be treated as one unit for the complete control.

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APPENDIX

List of vegetation met with at Bakrol

(*Gujarathi names are given wherever available in bracket*)

1. *Ischaemum rugosum* (*torona*)
2. *Themeda triandra* (*bhatadi*)
3. *Chrysopogon montanus* (*khadi*)
4. *Eremopogon foveolatus* (*kadvi zinzvi*)
5. *Desmostachya bipinnata* (*dabh*)
6. *Dichanthium annulatum* (*zinzvo*)
7. *Cymobopogon martini* (*rosha*)
8. *Apluda varia* (*karedi*)
9. *Iseilema laxum* (*machuri*)
10. *Aristida* sp.
11. *Setaria glauca*
12. *Panicum obscuarance*
13. *Ophiurus corymbosus*
14. *Manisuris granularis*
15. *Ischaemum pilosum*
16. *Coix lachryma Jobi*
17. *Heteropogon contortus* (*moti survali*)
18. *Andropogon pumilus*
19. *Chloris pallida*
20. *Pollinia argentea*
21. *Pennisetum ciliare* (*dhaman*)
22. *Panicum trypheron*
23. *Chloris barbata* (*kadpuchado*)
24. *Digitaria marginata*
25. *Echinochloa colona* (*samo*)
26. *Eragrostis pilosa*

STUDIES ON *ANNONA SQUAMOSA* (*SITAPHAL*) SEED
III. PRODUCTION AND COLLECTION IN HYDERABAD

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SEEDS contain fat to different extents and their utilization depends upon various factors such as the availability of seed and the case of extraction and purification of the fat.

The forests of Hyderabad State abound in trees of the custard apple (*Annona squamosa* Linn., *sitaphal*), and while the fruit is popular, the seed is thrown away as a waste material. Bhojraj Naidu and Achaya [1951] described the gross composition of the seeds from *A. squamosa* in Part I of this series and reported the isolation of a fat and also a protein from the defatted seed meal, whose high nitrogen content suggested its use as manure ; the fatty acid composition of the oil was closely similar to that of groundnut oil. Although the oil has been reported to have insecticidal property (Bhojraj Naidu, Mohan Babu Naidu, Osmani and Saletore, 1953) normal alkali refining in two stages gave a pale-yellow oil free from insecticidal activity though still not entirely acceptable to albino rats. Soap-making was tried with the oil, both raw and refined, by the semi-boiled and boiled processes, and the refined oil found quite suitable ; its similarity to groundnut oil suggested replacement of the latter, which could thus be made available for edible purposes.

Many seed fats remain only academically useful owing to difficulties of access to the trees, difficulties of collection of the seed, or high costs. This paper attempts to answer some of these problems with respect to *sitaphal* seed and attempts to evaluate approximately the availability of *sitaphal* seed in the State based on acreages and estimated number of trees per acre, and in the twin cities of Hyderabad and Secunderabad by enumeration of the fruit arriving at different markets (*mandies*). An actual collection of over 30 maunds of seeds in Hyderabad city in 1951 is described and the cost worked out and compared with that of other oilseeds. In this way, it has been estimated that the oil from the seeds could be made available in good condition at hardly one-third the price of say groundnut oil. It can, therefore, advantageously replace the latter which it closely resembles, in soap-making at a reduced price, and set free the more expensive groundnut oil for edible purposes.

A. SQUAMOSA PRODUCTION IN HYDERABAD STATE

Acreage of trees and relative production

Paranjpye and Siddaramayya estimated in 1933 that the acreage under *sitaphal* in the State amounted to 56,000 acres. These are found mainly in the forest areas of the six districts of Atraf-i-balda, Mahboobnagar, Medak, Nanded, Nalgonda and

Gulbarga being thus mainly in the fertile Telengana areas ; the acreage would comprise about one per cent of the total forest area in the districts and about 0·21 per cent of the total area of 263·4 acres [Hyderabad Government Bulletin on Economic Affairs, 1949].

Fruit production

The trees are 15-20 feet high, with oblong or elliptic leaves and pale-green flowers having six petals in a double row. The edible fruit weighs about 150-175 grams on an average ; 25-100 are borne per tree and since each acre contains on an average 400 trees, the yield of fruit per acre would amount to about 6,000 lb. Hence, 56,000 acres under *sitaphal* in the State are likely to yield about 1·5 lakh tons of fruit. It is interesting to note that in 1950, nearly a third of this yield was obtained from five villages (Chincholi, Kodangal, Yadgir, Lingsugur and Dharur) in Gulbarga district from their forest area of about 60,000 acres, which naturally is not exclusively utilized for *sitaphal* production [private communication from the Divisional Forest Officer, Gulbarga Division, Hyderabad Government, 1951].

Export

Inquiries from the railway authorities indicated that exports of *sitaphal* fruit were mainly towards Bombay by way of Tandur, Rukmapur and Dharur stations. From these three stations, during the 3-year period 1945-47, 1,785 tons of fruit were despatched, that is about 600 tons per year. In the 5-year period 1946-50, the average annual export of fruit amounted to 1,517 tons (valued by the Commissioner of Customs at 1·22 lakhs of rupees), with the high figure of 4,319 tons in 1950, nearly seven times the average annual export of 600 tons just four years earlier. This increase was shown in the larger number of railway wagons used for the purpose—22 in 1947 to 52 in 1950. Hence, though exports have been steadily mounting, they form only an insignificant proportion of the estimated production.

Imports

Surprisingly enough imports of fruit are also recorded by customs authorities amounting annually in the triennium ending 1947 to about ten tons.

Consumption

The *per capita* consumption of *sitaphal* fruit amounts, on the basis of a population of 163 lakh [Hyderabad Government Bulletin on Economic Affairs, 1949], to about 20·3 lb. or about 60 fruit per season.

Seeds, oil and oilcake production

Sitaphal seeds weigh on an average 0·30 gm. and average about 50 per fruit [Bhojraj Naidu and Achaya, 1951], thus amounting to about 15 gm. or about a tenth of the weight of the whole fruit ; fruit yield has been estimated at 6,000 lb. per acre, so that seed yield would come to about 600 lb. per acre. The total seed production in the State (from 56,000 acres) would amount to about 0·15 lakh ton, i.e., 336 lakh pounds Estimating the value of this, at a modest price of Rs. 200 per ton, based on the figure of Rs. 8 per maund in Table III, the value of this seed would be Rs. 30 lakh.

The oil content of the whole seed is 27·1 per cent and the potential availability of the oil in the State is about 91 lakh pounds ; even if half of this is lost through inefficient methods of oil expression, about 50 lakh pounds of oil are still obtainable.

The oilcake, still containing oil, would amount to something over 200 lakh pounds, and being richer in nitrogen (4·3 per cent) than cottonseed or coconut cake, will probably find use as a manure. The value of this cake based on nitrogen content at about Rs. 100 per ton which is less than that of most oilcakes, comes to easily more than Rs. 9 lakh a year ; though the oilcake has not been actually tested as manure on a large scale, it has been used in small amounts in the laboratory garden with no ill-effects, and there is no reason to believe that it will be inferior to any other oilcake of similar nitrogen content. The results are summerized in Table I.

TABLE I

Estimates relating to yearly sitaphal *production in Hyderabad State*

1. Extent of growth		56,000 acres
2. Production of fruit		1·5 lakh tons
3. Exports of fruit	ca.	1,500 tons
4. Imports of fruit	ca.	10 tons
5. Consumption of fruit		60 per head
6. Production of seed		336 lakh lb.
7. Production of oil (actually present)		91 lakh lb.
8. Production of oilcake		200 lakh lb.

Comparison with major and minor oilseeds

It is interesting to compare the figures now arrived at with at least one major and one minor oilseed. The acreage of groundnut seed in the State is about 30 times that of *sitaphal*, i.e. over 16 lakh acres [Private communication, 1951]. Compared to safflower (*karad*), a minor oilseed of the State, the tonnage of *sitaphal* seeds is about half the latter quantity of 30,000 tons annually in 1930 [Yuill, 1930], and about a sixth of the recent production [Marketing Report, 1948]. It is interesting to observe that *sitaphal* would potentially yield nearly four times as much oilseeds per acre as cultivated oilseed crops, where the general rate is 13-17 acres per ton of oilseed.

AVAILABILITY OF SEED IN HYDERABAD—SECUNDERABAD CITY

Collecting of information

The *sitaphal* tree fruits in the period September—December and fresh fruit arrive in markets (*mandies*) in the city early in the morning by cart or lorry. No records of the arrivals are kept, and it was only possible to take the word of the headman of each market regarding the number of each vehicle arriving daily, corroborating by enquiry from others in the market. Oral enquiries were necessary to estimate the variations in the arrivals. Each cart load was estimated as containing 3,000 fruit and each lorry load 25,000 fruit, figures arrived at by counting actual unloading.

Figures of arrivals at the markets

Estimates for the season in 1950 were made in this way for each of the 11 *mandies* visited, which cover practically all the major and minor arrivals of *sitaphal* fruit. Most of the fruit that arrives in the city is from the adjoining areas of Atraf-i-balda, Mahboobnagar, Medak, etc. Considering the number of approximations made, no great reliance is placed on the figures, but it is believed that a fair idea of the rough availability of, if not of the actual trade in, *sitaphal* has been arrived at, and will be useful for the utilization of the seed oil. The data obtained in the survey is presented in Table II.

TABLE II

Arrivals of sitaphal *fruit at different* mandies *in Hyderabad and Secunderabad during the fruiting season, September-December 1950*

Mandi	Arrivals mainly from	Arrivals of		Calculated quantity of fruit at 3,000 per cart and 25,000 per lorry (in lakhs)
		Carts	Lorries	
1. Chikkadpally	Bhonghir, Medchal	465	10	23·40
2. Moazamjahi	Mahboobnagar	..	487	121·75
3. Mangalhat	....	4	..	3·60
4. Puranaphul	....	580	480	128·10
5. Nayaphul	....	90	..	2·70
6. Uppuguda	Ibrahimpatam ; villages of Shadnagar, Shamshabad, Nagavaram, Maisaram, etc.	920	..	27·62
7. Mekala	Villages of Marmida, Mirkhanpet, Mankal, etc.	184	..	5·52
8. Dabirpura	Forests of Atraf-i-balda	360	..	10·80
9. Yakutpura	....	122	..	3·66
10. Mushirabad	....	122	5	4·91
11. Secunderabad	Alwal, Medchal	915	50	39·96
	TOTAL	3,762	1,032	372·02

Discussion

Table II indicates an estimated availability in the *mandies* of the city of nearly 372 lakh fruit during the 1950 season. Many merchants in the markets visited were of the opinion that the 1950 season was an abnormally poor one, and that due to

the failure of the crop only about a fifth of the normal arrivals appeared in the markets. Some slight confirmation of this fact is obtained by comparing the figures just obtained with the estimated fruit production in the whole State of 1·5 lakh tons by weight or about 10,000 lakh fruit in number : the figure for the cities is just about 3·8 per cent of the total which is improbably low ; five times this figure, i.e. 19 per cent would be more likely for the proportion consumed in the capital. On the other hand the figures of 56,000 acres under *sitaphal* on which the above-mentioned production figure is based, is again only an estimate, and liable to all the errors thereby implied.

In any case 372 lakhs of fruit would yield 1·8 lakh pounds of expressed oil (as different from potential oil) if all the seed available in the metropolis were to be collected. Hence, there is enough raw material in the twin cities of Hyderabad and Secunderabad to warrant expression of oil from *sitaphal* seed on an industrial scale. How much can actually be collected will depend on too many factors to evaluate with even remote certainty.

Sample collection of seed in the city

Actual collection

Collection of *sitaphal* seeds from the *mandies* was attempted during the 1951 season, and our grateful thanks are due to the Health Department of the Municipal Corporation of Hyderabad, who put their men and facilities at our disposal. *Sitaphal* refuse (seeds, skins, etc.) are scattered around many of the *mandies* in appreciable quantities, but since it is apparently sold by the headman of the market to farmers for manurial purposes at about Rs. 3 a cartload, some difficulty was experienced in collection ; an understanding was, however, reached that as far as possible only the seeds and not skins which are of real manurial value, would be collected. From the five markets of Chikkadpally, Puranaphul, Yakutpura, Dabirpura and Chanderghat Municipal Ward, about 95 bags of *sitaphal* refuse was brought to the laboratory premises ; working at the rate of 100 seers or 2½ maunds per bag, this equals about 238 maunds of material.

Cleaning of the material

Two women labourers worked, for about six hours a day for six weeks working up the seeds to reasonable freedom from stones, skins and other waste matter ; the cleaned seeds were estimated eventually to contain only about five per cent contaminants. A five-stage operations was effected :

1. *Using a 4-mesh sieve.* The largest-sized skins (especially) were removed by pouring the refuse against a 4-mesh screen at an angle.
2. *Using a 16-mesh sieve.* Similar treatment with this sieve removed small sized skins, stones and very small seeds.
3. *Floatation.* The material above, containing about 25-30 per cent seeds, was floated in troughs of water, when a large part of the contaminants sink to the bottom, while the seeds being lighter than water float on

top. The contaminants comprise about 20 per cent of hard, dry skins, grasses and straws, sticks, etc. The seeds were sun-dried in the open.

4. *Winnowing.* Small-sized skins, damaged seeds and small stones were removed by hand, special care being taken to remove the latter since they cause damage to decorticating machinery. The seeds were finally contaminated with only five per cent extraneous material.

Cost

About 30·5 maunds of seed were thus collected and stored in gunny bags from 238 maunds of starting material, i.e. about 13 per cent or one-seventh. Side by side about 10 cartloads or 125 maunds refuse, mainly skins from the first three operations described above, were collected and used in the laboratory garden as manure. Estimates of costs in Hyderabad currency for the 234 maunds actually collected were made and are shown in Table III.

TABLE III

Statement showing cost of sitaphal *seed per maund of 40 seers in Hyderabad-Secunderabad City*

	Hyderabad currency		
	Rs.	As.	Ps.
1. Cost of total *sitaphal* refuse (238 maunds) or 24 carts at Rs. 3 per cart	72	0	0
2. Cost of labour for collecting and loading at Rs. 1/4 per cart	30	0	0
3. Cartage of refuse from *mandies* to laboratory premises at Rs. 2/8 per cart	60	0	0
4. Wages of two women labourers for 6 weeks of 6 days each at Rs. 1/8 per day for separating seeds from refuse	108	0	0
TOTAL	270	0	0
Less value of 10 cartloads (by-product produced) manure at Rs. 3 per cart	30	0	0
Total cost of 30½ maunds of seeds	240	0	0
Cost per maund of 40 seers of seed	7	14	0
Add cost of gunny bag 1 maund capacity	1	0	0
Add contingencies	0	8	0
Total cost of seed per maund including labour, gunny bag, etc.	9	6	0
Total cost of seed per maund (Indian currency)	8	0	0

The total cost per maund of seed works out to Rs. 9-6 in Hyderabad currency or about Rs. 8 in Indian currency (Rs. 7 Hyderabad=Rs. 6 Indian). This compares very favourably with the Rs. 25 per maund which is the prevalent price of groundnut and would more than compensate for the cost of refining necessary to remove the insecticidal principle before utilization of the oil either for catering or, in the absence of actual tests on human beings, for soap-making purposes [Bhojraj Naidu, *et al.*, 1953].

The major difficulty will be collection of *sitaphal* seed. The work described in the paper shows that even a small organized collection was easily able to gather one

ton of seed from market sweepings at four markets for about three weeks. There is therefore, reason to feel that with organized large-scale collection over the whole season a fair proportion of the 3,000 tons of seed estimated to be available in the metropolis can be obtained. Moreover, interest in the pulp is growing. A Bombay concern is attempting to can *sitaphal* pulp while a fruit research station has worked out a successful process for the same ; this dried pulp is being marketed in Hyderabad State on a cottage-industry basis. Once the fruit is centralized, the seed will be much more easily obtainable. Finally, the need to propagate information regarding the value of this, as indeed of other indigenous materials, through the medium of radio, press and agricultural departments, is emphatically stressed.

Summary

Based on the estimated 56,000 acres under *Annona squamosa* (*sitaphal*), mainly in Telengana, the annual production of fruit in Hyderabad State is estimated at 1·5 lakh tons ; annual exports averaged about 1,500 tons and imports about 10 tons. From this production could be obtained an estimated Rs. 30 lakh worth of seed, 50 lakh pounds of actual expressed fatty oil and 200 lakh pounds of oilcake worth about Rs. 9 lakh yearly.

An estimate of arrivals during the 1950 season at *mandies* (markets) of Hyderabad-Secunderabad City gave a figure of 372 lakh fruit, from which 1·5 lakh pounds of oil could actually be expressed annually. There is reason to believe that the 1950 season was a poor one, perhaps only 20 per cent of the normal.

An actual collection organized at several *mandies* yielded 238 maunds of *sitaphal* refuse : cleaning by the use of sieves, floatation, winnowing and hand-picking gave 30·5 maunds (13 per cent) of seeds contaminated with only about five per cent foreign matter. Ten cartloads of manure accumulated as useful by-product. An estimate of costs indicated a maximum of Rs. 8 (Indian currency) per maund for *sitaphal* seed.

The need for collection pools and propaganda is emphasized.

Acknowledgement

Our grateful thanks are due to Dr S. Husain Zaheer, Director, Central Laboratories for Scientific and Industrial Research, for his keenness in pushing forward this work. One of us (N. Bhojraj Naidu) is indebted to the Board of Scientific and Industrial Research (Hyderabad-Deccan) for the award of a research grant.

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NOTES ON *CASSIDA CIRCUMDATA* HBST., *CASSIDA INDICOLA* DUV. AND *GLYPHOCASSIS TRILINEATA* HOPE (COLEOPTERA ; CHRYSOMELIDAE : CASSIDINAE) AS PESTS OF SWEET POTATO (*IPOMOEA BATATAS*) AT KANPUR

By B. K. Varma, M.Sc. (Agri.), Research Fellow, Section of the Entomologist to Government, U. P., Kanpur

(Received for publication on 30 September 1953)

CASSID insects are commonly known as tortoise beetles. They are all plant-feeders. The species known to damage sugar beet is *Cassida nebulosa* L. in Central Europe [Wahul, 1921, Wonoriecka, 1925], Finland [Linnaniemi, 1917], Russia [Vasilev, 1922-23], and Japan [Kumroyama, Kuri Baryashi and Ostuma, 1925], to sweet potato are *Typophorus viridicyaneus* in America [Brannon, 1938] and *Aspidomorpha miliaris* F., in Philippines, New Guinea, Java [Franssen, 1934] and Malaya and to artichoke is *Cassida virdis* L., in France [Noel, 1914]. In India *Aspidomorpha miliaris* F. [Aiyer, 1940 ; Fletcher, 1940 ; Report of the Proceedings of the Entomological Meeting, 1917] and some unidentified beetles, belonging to the genus *Cassida*, have been recorded to attack sweet potato and weeds belonging to the family Convolvulaceae. At Kanpur, *C. circumdata* Hbst., *C. indicola* Duv., and *G. trilineata* Hope have been recorded for the first time as pests of sweet potato. A short account of the life history of *C. circumdata* and *C. indicola* and description of all the three species as studied by the writer at Kanpur during 1951 and 1952 are as follows.

C. CIRCUMDATA

This species appears earlier than *C. indicola*, in the beginning of August and is observed till late in November in the field. Both grubs and adults feed upon the leaves and cut irregular holes. A badly eaten leaf dries up soon.

The eggs are laid singly, generally on the lower surface of the leaves and mostly adjacent to the veins. They are covered with a thin boat-shaped parchment which is an abdominal secretion of the female beetle. Freshly laid eggs are light blue in colour, oval in shape, 1 mm. long, 0·4 mm. broad and become bluish green at the time of maturity. The egg period ranges from 3-5 days.

The young grub is compodeiform in shape, greenish pale in colour, 1·12 mm. long and 0·46 mm. broad. It undergoes four moults before pupation which can be easily observed by the moulted skins attached in sequence with the caudal end of the grub. The mature grub is greenish in colour with the body margins slightly pale. It is 5 mm. long and 2·6 mm. broad. The pronotum has eight spines arranged marginally and the first two in the front on either side of the mid-longitudinal line have a common base. Each of the meso and metanotum has four spines arranged in pairs on the lateral sides. All abdominal segments except the ninth carry a pair of spines one on each side, which are directed outwards. The spines on the seventh abdominal segment are comparatively longer than the spines on the preceding abdominal segments and eight abdominal segment.

The ninth segment has a pair of simple forceps-like horny spines which are directed backwards providing an attachment for the moulted skin of the earlier stages of the grub. The spines carry spinules which are arranged racemosely and the thoracic spines are stouter than the abdominal spines.

The grub period lasts for 10-15 days, the duration of the first to fourth moult being 2-3, 2-3, 3-4, and 3-5 days respectively.

Pupation occurs on the lower surface of the leaves. The pupa is 4·6 mm. long, 2·3 mm. broad, oval in shape and greenish yellow in colour. It is subtruncate anteriorly, the posterior $\frac{1}{4}$th part is covered with the moulted skin of the grub and and is firmly attached with the leaf surface through its caudal end. The outer margin of the pronotum is beset with 52 simple spines and each of the first five abdominal segments carries a pair of spines, one on each side, in the form of a leaflet bearing spinules not exceeding ten in number. Rest of the segments carry simple short spines except last which bears a pair of long spines, curved on the dorsum along with the serially attached casted skins of the grub.

The pupal period ranges between 6-8 days.

The adult beetle is deeply convex, rotundate, 5·1 mm. long, 4·6 mm. broad and shining greenish yellow in colour. The margins appear reticulate and beautifully patterned dorsally with a black ' U ' shaped mark on the elytra and a mid-sutural band.

The total life cycle takes 19 to 28 days.

C. INDICOLA

This species is found along with *C. circumdata* in the field, though in lesser numbers. The eggs are laid on the lower surface of leaves, generally in pairs, but sometimes singly or three in number. They are concealed under a thin brown parchment which is made out of a fluid secreted by the female beetle. Freshly laid eggs are yellowish white in colour, oval in shape, 0·92 mm. long, 0·4 mm. broad and turn creamy white at the time of maturity. The egg period is 3 to 4 days.

The young grub is compodeiform in shape, yellowish brown in colour and measures 1 mm. in length and 0·44 mm. in breadth. It undergoes four moults before pupation and unlike the grub of *C. circumdata* it carries the moulted skin in the form of a pad which is attached with the anal spines and is turned over the dorsum. The full grown grub is yellowish brown in colour and measures 4·8 mm. in length and 2·6 mm. in breadth.

The arrangement of the spines on the thorax and the abdomen is similar to that in *C. circumdata*. The spines are of uniform size except the spines of the penultimate segment which are longer and directed down wards and the spines of the anal segment are the longest and curved backwards on the dorsum.

The grub period lasts from 8 to 14 days and the duration of each of the first two moults is 2-3 days, while that of the last two moults is 2-4 days each.

The grub pupates on the lower surface of the leaves. The pupa is 4·5 mm. long and 2·2 mm. broad, oval in shape subtruncate anteriorly and yellowish brown with greenish tinge. The last four segments of the abdomen are covered with the amassed moulted skin. The outer margin of the pronotum of the pupa is beset with 56 spines, intermixed with long and short ones. The lateral margins of each

of the first five abdominal segments possess spines which are leaflet like. The sixth, seventh and eighth segments bear minute spines laterally and the ninth one has a pair of long spines, strongly chitinized, running parallel and curved backwards on the dorsum of the pupa.

The pupal period is 4 to 7 days.

The adult beetle is convex, sub-oval, 4·5 mm. long, 3 mm. broad and dull green with light brown patches on the elytra.

The total life cycle occupies 15 to 25 days.

G. TRILINEATA

This species is larger than the preceding two species, 6·2 mm. long, 4·2 mm. broad and blackly patterned against pale yellow background. The pronotum has three longitudinal stripes arranged in a figure of '8' with an incomplete mid-posterior arc, and extra sutural band and a small patch on the distal explanate margin which coalesces with the stripe. The apical five segments of the antennae are black.

Appearing quite late in the season, it is found along with the *Cassida* sp. bu not so abundantly as the latter two species.

The combined attack of all the three species causes sometimes considerable damage to sweet potato crop and, therefore, further investigation of the species with a view to their control will not be without profit.

ACKNOWLEDGEMENT

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REVIEWS

FIELD EXPERIMENTATION WITH FRUIT TREES AND OTHER PERENNIAL PLANTS

By S. C. Pearce

(*Technical Communication No. 23 of the Commonwealth Bureau of Horticulture and Plantation Crops, England, 1953, pp. 131, Price 10 s. or $ 1·40*)

THIS book provides an excellent source of reference on field experimentation with perennial and fruit trees. A large section of the material covered in this book has grown out of the experiences of the author as a member of the Statistics Section at the East Malling Fruit Research Station in England and of other research workers at this research station. This book is primarily addressed to the practical experimenter who has some elementary training in the use of modern statistical methods but a statistician who is called upon to advise in the planning of experiments on tree-crops will also find it to be useful.

Experimental designs which have been or likely to be found useful in horticultural problems have only been discussed and to that extent the scope of the book is limited. In spite of this, the book covers a variety of topics and contains the following chapters:

(1) Introduction, (2) Some simple designs, (3) Some more complicated designs, (4) Callibration, (5) Blocks, Plots and Replications, (6) Trial designs in relation to the subject of investigation, (7) The analysis of results, (8) Some mishaps and remedies, (9) The measurement of perennial plants. The book also has four useful appendices illustrating various computational methods. The book concludes with a comprehensive bibliography and author index.

Different types of ' simple ' and some ' complicated ' designs which one usually comes across in the study of annual crops, have been listed for illustrating different situations under which these designs could be employed. The author has preferred not to append to each design a worked out example and, in keeping with the broader aspects of experimentation, has correctly devoted considerable attention to the practical know-how of such designs in relation to horticultural problems. The author believes perhaps rightly that inherent variability of experimental plant material in horticultural experiments is a much more disturbing source of variation than the positional variation and has, therefore, made no attempt to discuss those quasi-factorial and factorial designs which are usually recommended to cut down the block size in experiments on annual crops. In fact, the book contains only a meagre discussion of the well-known factorial schemes.

It is well known that the provision of adequate guard rows in experiments on tree crops makes quite a heavy demand on the available experimental resources. The author has shown in a pictorial way the various methods of providing both internal and external guard rows and has also indicated where they are essential and where they can be easily dispensed with. While discussing the manurial prob-

lems of perennial species, Dr Pearce has pointed out that since optimum application of treatments will change with theage of trees, there is no point in determining such optimum requirements at a particular time. He has indicated a progressive plan of experimentation for determining a manurial schedule which perhaps many will dispute. A comprehensive scheme of experimentation for determining the manurial schedule for a given life cycle of tree-crops is necessarily much involved and still remains an open question.

Several other techniques of interest to the practical experimenter have also been discussed in this book ; they are : covariance analysis, transformation of variables in the analysis of variance, handling of missing plot data, catalogue of uniformity trials in relation to the number of trees per plot and the analysis of several years data. The presentation of different techniques of analysis in the form of four appendices is very instructive and is a useful feature of this book.

This is the first book of its kind to be published on horticultural experiments. It is written in a non-mathematical language and should prove to be of great use for the practical experimenter. (U. C.)

RICE

By D. H. Grist

(*Published by Longmans Green & Co., Ltd., London, 1953, pp. 331, Price 35* s. *or Rs. 25-7*)

THE publication of this book is most opportune as at present the problem of increasing rice production is engaging the serious attention of all the South-East Asian countries. Sir Harold Tempany in his introduction to this book rightly points out that the peace and security of the world at present is intimately connected with the successful solution of this problem. There are very few books published on this most important crop and there is no publication so far on the recent development and advances and the various aspects of rice production since the publication of Copeland's book on rice in 1924 and Ramiah's popular 'Hand Book on Rice' in 1937. It is therefore certain that this book will be welcomed by all those interested in rice production. The author has to be congratulated for his ability in compiling all the scattered information from nearly more than 300 references and presenting the subject in a concise form, illustrated with beautiful photographs.

The Volume consists of 17 chapters covering a wide range including the origin and botany of rice plant, cultivation and manuring practices followed in various countries, mechanical cultivation, pests and diseases, storage, milling, nutritive value, and production and distribution.

The information given on the origin of rice is incomplete and does not include latest references on the subject. The subject of the origin of rice is complicated due to the existence of nearly 23 species in the genus *oryza* distributed in the various parts of the world. *O. perennis* which has a distribution covering both Africa and India is probably the ancestor of cultivated rice. The author could also have very well pointed out the broad classification of the cultivated rices, viz. *japonica* and *indica*, and their distribution and characteristics.

Importance of water and control of drainage for successful rice cultivation and the need for full collaboration between Agricultural Departments and the Irrigation Engineers for the successful large-scale irrigation projects have been properly stressed. The chapter on mechanization of rice cultivation is interesting. The methods of complete mechanization as adopted in the U. S. A. have been described in detail and their possibilities and limitations of extending these to Asian countries have been discussed and the need for modifications for the present conditions and the designing of implements with great manoeuverability to suit conditions prevailing in Asian countries has also been emphasised.

While soils and irrigation practices are discussed exhaustively, certain statements are made which are contradictory. For instance, in chapter III, page 29, the author agrees with the view that maximum yields cannot be expected from short duration crops. But later in chapter VIII, page 136, the author feels that local conditions will determine the raising of two crops of shorter maturation period and that such crops may produce a heavier yield than one crop of long maturation period. It is not correct to generalise that shorter maturation varieties do not give as much yield as long duration varieties.

In chapter III, page 23, the author mentions that very fine silt frequently has an unfavourable effect on plant growth. The author perhaps is referring to contaminated silt as found in parts of Malaya. In India rice growers are practically anxious to use silt-laden water for the rice fields when first freshes are received in the beginning of the monsoon.

The author in dealing with fertilizers and manures is of the opinion that the requirement of first importance for many years is organic matter which he assumes is usually available in large quantities in many paddy growing regions.

Though the importance of organic matter like green manures, farm yard manure, etc. are well-known, the question really is their availability and in many countries the choice is between inorganic fertilizers and no fertilizers. However, the author comes to the right conclusion that crop yields can be raised by the extensive use of natural manures and artificial fertilizers. The author has also rightly pointed out that heavier dressings of artificial fertilizers for rice are usually used in countries with temperate climate and has cautioned against such heavy dressings for tropical and sub-tropical countries. From a division of rice growing areas, according to the latitude and the average yields obtained in such places, an interesting conclusion arrived at by the author is that rice production in the world could be maximised by concentrating attention on areas between 21° to 30° latitude which includes India and China. He is therefore optimistic of raising the yield in India and states : 'Indeed, if Indian yields could be raised to the level assumed to the characteristic of this latitude, it should go far to lessen prevention of the world rice shortage for some years to come'.

New scientific approach to the study of paddy soil regarding existence of oxidation and reduction zones in water-logged soil has been briefly described from the point of view of cultivation, manurial practices and plant growth. As a result of

this study sub-surface application of nitrogenous fertilizers is recommended to increase its efficiency. The author considers that further work in this direction is desirable to explain some phenomena regarding plant growth especially under submerged conditions which have hitherto remained obscure.

In dealing with pests of paddy and their control, the author describes the old methods of control before the introduction of the modern toxic insecticides like the synthetic hydrocarbons and the organo-phosphorous compounds. However in the last para of chapter VI, passing mention of the potential value of the hydrocarbons is made. For a book which is published in 1953, more recent information on the pest control measures as also the use of recent nomenclature for naming insects would be expected.

When chapters on varieties, classification, origin and history of rice have been included in the book, it would have been better if the author had devoted a separate chapter on rice breeding which, as the author has said, is one of the four main ways of securing better yields of rice.

In a book which covers such a wider range such omissions cannot be considered serious and as mentioned before the book is sure to be welcomed by all interested in rice and no worker in the field should be without a copy of this publication. (S. P.)

BETWEEN US AND HUNGER

By C. Mayadas

(*Published by the Oxford University Press, Bombay, 1954, pp. 157, Price Rs. 10*)

MR C. Mayadas belonged to the Indian Agricultural Service for more than three decades during which he occupied important technical as well as administrative posts in the Agriculture Department of what is now known as Uttar Pradesh. He therefore had ample opportunities of studying agricultural problems in this country in their proper setting and also to think about their solution. Mr Mayadas is therefore well qualified to write a book such as this on problems facing food production in this country. The problems dealt with are not altogether new or unknown but the manner in which he deals with them has certain amount of freshness and bears unmistakable evidence of the author's long experience in dealing with agricultural programmes.

The book is divided into the following 12 chapters.

1. The Gravity of the World Food Situation
2. Waste Not, Want Not
3. The Conservation of Soil Wealth
4. Surplus Cattle and other Crop Pests
5. The Consolidation of Holdings
6. Reclaiming Land
7. Dry Farming

8. How to Conserve Our Water Resources
9. Fertilizers and Intensive Farming
10. Mechanization, the Man and the Bullock
11. Mechanising to Produce More
12. Looking Ahead

In all these chapters specific problems relating to the subject matter are dealt with. He has given suggestions which in his opinion would tend to make agricultural production of advantage to the farmer as well as the people. Mention may specially be made of his treatment of dry farming as also of the place of mechanisation in agricultural economy of the country. He has discussed mechanisation as an aid to improve farming practices, and the relative positions of mechanical and bullock power.

The book is well produced, neatly printed and copiously illustrated with photographs. It is indeed a readable volume and will be found helpful by those interested in the improvement of Indian Agriculture. (U. N. C.)

AGRICULTURAL ECONOMICS

By D. S. Chauhan

(*Published by Messrs Laxmi Narayan Agarwal, Agra, 1953, pp. 345, Rs. 12*)

ACCORDING to the author 'the book is primarily intended to provide a clear and full understanding of the subject of Agricultural Economics'. The first three chapters are devoted to a theoretical discussion of the nature and scope of agricultural economics, the place of agriculture in national economy and the special features of the agricultural economy. Problems of farm management are briefly discussed in the fourth chapter. The next two chapters contain an interesting discussion of economic transition in India and famine relief. The last two chapters, dealing with the utilization of land, water and power resources, are fairly informative and will be very useful to the general reader. The author has brought together a good deal of information on different aspects of resource utilization such as land-use, soil conservation, forests, land reclamation, flood control and the possibilities of irrigation and the various sources of power and their development. The treatment of the subjects is uneven and at places the analysis is not as rigorous as it should be. This is probably because the author wanted to make the book 'interesting to the non-specialists and at the same time to provide something for the specialists'. Problems of land tenure as well as agricultural finance which, judged by any measure, are among the most important factors in the development of Indian agriculture, have been completely left out. A discussion of these problems would have considerably enhanced the usefulness of the book. Nevertheless, the book is a useful addition to the literature on Indian Agriculture. (R. N. P.)

BHAGIRATH

A MONTHLY devoted to irrigation and power.

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Reference to literature arranged, alphabetically according to authors' names, should be placed at the end of the article, the various references to each author being arranged chronologically. Each reference should contain the name of the author (with initials), the year of publication, title of the article, the abbreviated title of the publication, volume and page. In the text, the reference should be indicated by the author's name, followed by the year of publication enclosed in brackets ; when the author's name occurs in the text, the year of publication only need be given in brackets. If the reference is made to several articles published by one author in a single year, these should be numbered in sequence and the number quoted after year both in the text and the collected references.

If a paper has not been seen in original it is safe to state 'original not seen'. Sources of information should be specifically acknowledged.

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